SB4241E00
Apr. 2007

Service Manual

G420FE LP/Dual Fuel Engine
G420F LP/Gasoline Dual Fuel Engine

G15S-5, G18S-5, G20SC-5
GC15S-5, GC18S-5, GC20SC-5
G20E-5, G25E-5, G30E-5
GC20E-5, GC25E-5, GC30E-5, GC33E-5

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the “Safety” section of the Service or Technical Manual. Additional safety precautions are listed in the “Safety” section of the owner/operation/maintenance publication.
Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

⚠ WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.
Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

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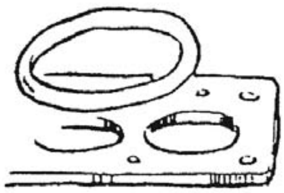
Chapter 1. GENERAL INFORMATION

Precautions before Service

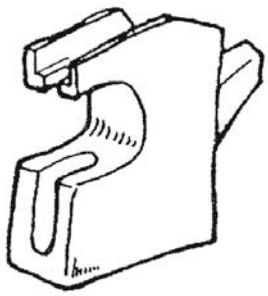
Removal and Disassembly



1EN0022

For prevention of wrong installation or reassembly and for ease of operation, put mating marks to the parts where no function is adversely affected.

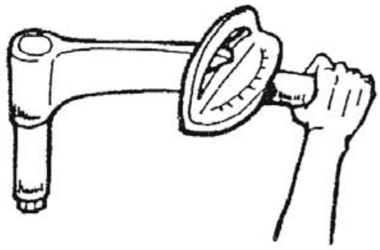
Special Tool



1EN0019

Be sure to use Special Tools when their use is specified for the operation.
Use of substitute tools will result in malfunction of the part or damage it.

Tightening Torque



1EN0020

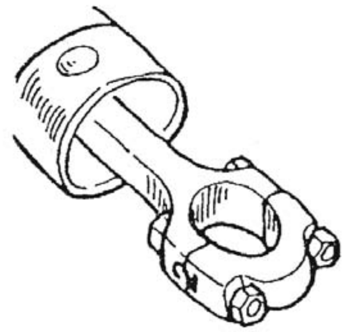
Tighten the part properly to specified torque.

Sealant

1EN0021

Use specified brand of sealant.
Use of sealant other than specified sealant may cause water or oil leaks.

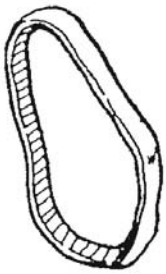
Replacement Part



1EN0018

When oil seal, O-ring, packing and gasket have been removed, be sure to replace them with new parts.
However, rocker cover gasket may be reused if it is not damaged.

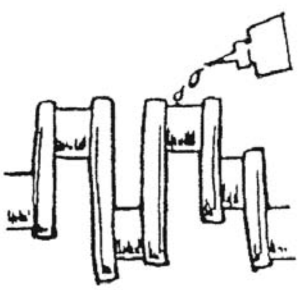
Rubber Parts



1EN0023

Do not stain timing belt and V-belt with oil or water. Therefore, do not clean the pulley and sprocket with detergent.

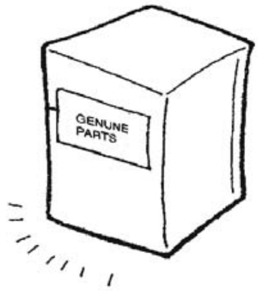
Oil and Grease



1EN0024

Before reassembly, apply specified oil to the rotating and sliding parts.

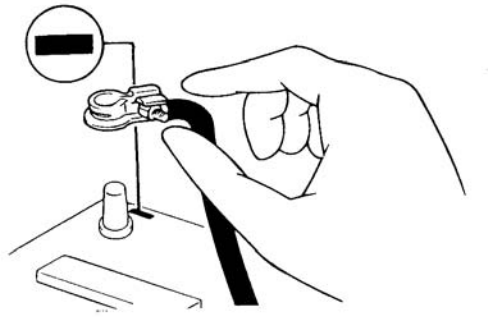
Genuine Part



1EN0025

When the part is to be replaced, be sure to use genuine part.
For selection of appropriate parts, refer to the Parts Catalog.

Electrical System



1. Be sure to disconnect the battery cable from the negative(-) terminal of the battery.

2. Never pull on the wires when disconnecting connectors.

3. Locking connectors will click when the connector is secure.

4. Handle sensors and relays carefully. Be careful not to drop them or hit them against other parts.

Precautions for catalytic Converter

⚠ CAUTION

If a large amount of unburned gasoline flows into the converter, it may overheat and create a fire hazard. To prevent this, observe the following precautions and explain them to your customer.

1. Use only unleaded gasoline.

2. Do net run the engine while the truck is at rest for a long time. Avoid running the engine at fast idle for more than 5 minutes and at idle speed for more than 10 minutes.

3. Avoid spark-jump tests. Do spark-jumps only when absolutely necessary. Perform this test as rapidly as possible and, while testing, never race the engine.

4. Do not measure engine compression for an extended time. Engine compression tests must be made as rapidly as possible

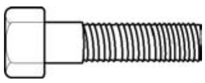
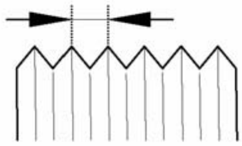
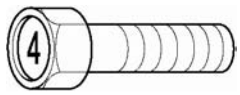
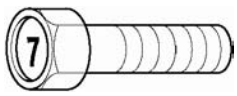
5. Do not run the engine when the fuel tank is nearly empty. This may cause the engine to misfire and create and extra load on the converter.

6. Avoid coasting with the ignition turned off and during prolonged braking

7. Do not dispose of a used catalytic converter together with parts contaminated with gasoline or oil.

Tightening Torque

Tightening Torque Table of Standard Parts

Bolt nominal diameter(mm)	Pitch(mm)	Torque (kg·m)	
		Head mark 4	Head mark 7
			
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0
M12	1.25	3.5 ~ 4.5	6 ~ 8
M14	1.2	7.5 ~ 8.5	12 ~ 14
M16	1.5	11 ~ 13	18 ~ 21
M18	1.5	16 ~ 18	26 ~ 30
M20	1.5	22 ~ 25	36 ~ 42
M22	1.5	29 ~ 33	48 ~ 55
M24	1.5	37 ~ 42	61 ~ 70
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0

NOTE: The torques shown in the table are standard vales under the following conditions.

1. Nuts and bolt are made of steel bar and galvanized.

2. Galvanized plain steel washers are inserted.

3. All nuts, bolts, plain washers are dry.

NOTE: The torques shown in the table are not applicable,

1. When spring washers, toothed washers and the like are inserted.

2. If plastic parts are fastened.

3. If oil is applied to threads and surfaces.

NOTE: If you reduce the torques in the table to the percentage indicated below under the following conditions, it will be the standard value.

1. If spring washers are used : 85%

2. If threads and bearing surfaces are stained with oil: 85%

Recommended Lubricants and Capacities

Recommended Lubricants

Lubricant	Specification	Remarks
Engine Oil	API Classification SJ or above	SAE 10W30 or SAE 5W30
Coolant (Antifreeze)	Automotive antifreeze suitable for gasoline engines having aluminum alloy parts	Concentration level 50%(normal) Concentration level 40%(tropical)

Lubricant Capacities

Description		G(C)18S-5, G(C)20SC-5	G(C)20/25/30E-5
Engine Oil (liters)	Oil Pan	3.7	3.7
	Oil Filter	0.3	0.3
	Total	4.0	4.0
Coolant (liters)	Engine	3.0	3.0
	Radiator & Hoses	5.5	5.5
	Total	8.5	8.5

Engine Model and Engine Serial Number

Engine Model	Fuel Type	Emission Regulation
G420FE	LP/Dual Fuel	EPA/CARB* 2007 Compliant
G420F	LP/Gasoline/Dual Fuel	

* EPA: Environmental Protection Agency

* CARB: California Air Resources Board

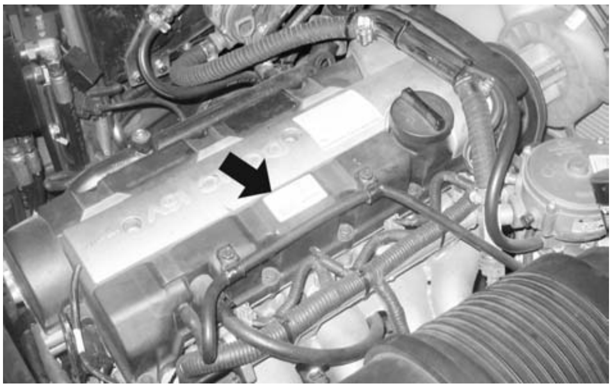
G420FE Engine

- Comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Certified LP/Dual Fuel System available
  - Closed loop LP Carburetion system
  - Closed loop MPI Gasoline system
- 3-way Catalytic Muffler is standard

G420F Engine

- Not comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Standard LP/Gas/DF/Dual Fuel System available
  - Open loop LP Carburetion system
  - Closed loop MPI Gasoline system
- Muffler is standard

Indication of Engine Model and Serial Number



Engine Model	Engine Serial Number
G420FE/G420F	30700001 to 39999999

Features and Benefits of G420FE/G420F Engine

- Al head with valve seat inserts
  - Aluminum head and valve seat system
- DOHC 16 valve system
- Durable timing belt system
  - Durable timing belt material and rubber-sealed cover
- Distributorless Ignition system (coil on plug)
- Electronic control system by ECM (Engine control module)
  - Drive-by-wire system
  - Higher efficiency and lower fuel consumption
  - Min./Max. governor control
  - Automatic engine protection from overheating and/or low engine oil pressure
  - Automatic transmission protection from overheating
  - Engine diagnostics by service-tool software
  - Forklift ground speed limit (optional)

General Specification

	G420FE Engine	G420F Engine
GENERAL DESCRIPTION		
ENGINE TYPE:	Water-cooled, Inline 4-Cycle, 4-Cylinders	
COMBUSTION SYSTEM:	Semi-Rent Roof	
INTAKE MANIFOLD	Cast Aluminum (with injector ports)	
EXHAUST MANIFOLD	Cast Iron, Dry	
VALVE CONFIGURATION:	DOHC, 4 Valves per Cylinder	
VALVE LIFTER/LASH ADJUSTER	Hydraulic Lash Adjuster	
VALVE ROTATOR	Intake/Exhaust Rotator	
CAMSHAFT DRIVE	Timing belt system (25.4 mm Toothed Belt)	
DISPLACEMENT:	1,975 cc (120.5 cid)	
BORE x STROKE	82mm (3.23 in) x 93.5 mm (3.68 in)	
BLOCK STRUCTURE	Grey Cast Iron	
HEAD STRUCTURE	Aluminum with seat inserts	
COMPRESSION RATIO:	9.4:1	
COMPRESSION PRESSURE:	1,450 kPa (210 psi)	
VALVE TIMING:	Intake Valve: 2° BTDC(Open)/ 16° ABDC(Close)	
	Exhaust Valve: 6° BBDC(Open)/ 2° ATDC(Close)	
FIRING ORDER:	1-3-4-2	
WEIGHT:	170 kg (Dry)	
ENGINE ROTATION:	Counter-Clockwise (CCW) when viewed from Flywheel End	
FUEL TYPE:	LPG, Gasoline, Dual Fuel (LPG or Gasoline)	
CRANK VENTILATION	Foul Air System with PCV	
IGNTION SYSTEM		
IGNITION TYPE:	Distributorless (coil on plug)	
IGNITION TIMING:	Electronic controlled by ECM	
POWER TRANSISTOR	Ignition coil driver	
IGNITION COIL:	12 V operation volt, 4 coils (coil on plug)	
SPARK PLUGS:	Platimum Spark Plug (Air Gap: 0.8mm)	
LUBRICATION SYSTEM		
OIL PRESSURE:	167 kPa (24 psi) @ low Idle (90-100C oil temperature)	
OIL TEMPERATURE:	Upper Limit: 125°C (257°F)	
	Recommended: 99 - 110°C (210 - 230°F)	
	Lower Limit:80°C (176°F)	
OIL PAN	Cast Aluminum	
OIL PAN CAPACITY	3.7 L (EXCLUDES OIL FILTER)	
OIL FILTER:	0.3 L	
ENGINE OIL SPECIFICATION:	API - SJ, SAE 10W30 or SAE 5W30	
COOLING SYSTEM		
WATER PUMP ROTATION:	V-Belt Drive - Clockwise (CW) when viewed from engine front	
THERMOSTAT:	Opening Temperature: 82°C (180°F)	
	Fully Open Temperature: 95°C (203°F)	
COOLING WATER CAPACITY:	3.0 L (block only)	

General Specification

	G420FE Engine	G420F Engine
LP FUEL SYSTEM		
LP FUEL SYSTEM	Closed loop LP Carburetion System	Open loop LP Carburetion System
MIXER:	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)
REGULATOR:	Two-Stage Negative Pressure Regulator (Model: N-2007)	Two-Stage Negative Pressure Regulator (Model: N-2001)
FUEL TRIM VALVE (FTV):	Dual Dither System	No FTV
FUEL FILTRATION:	40 Microns Maximum	40 Microns Maximum
GASOLINE FUEL SYSTEM		
GASOLINE FUEL SYSTEM	Closed loop MPI System and In-Tank Fuel Pump System	
FUEL PUMP MODULE	Electric Fuel Pump (12V)	
	Fuel Filter & Strainer	
	Gasoline Pressure Regulator (3.5 bar)	
FUEL INJECTOR ASS'Y	Electric Fuel Injector (12V)	
ENGINE ELECTRIC		
ENGINE CONTROL MODULE(ECM):	12 V operation volt, 48 pins of I/O	
CRANK SENSOR	Magnetic Inductive type	
CAM SENSOR	Hall sensor	
TMAP:	Intake Air Temp. & Manifold Absolute Press. Sensor	
PEDAL ANGLE SENSOR:	Two-Output Signals (built in Accelerator Pedal)	
OXYGEN SENSOR:	Dual Oxygen Sensor System	Gasoline : One Oxygen sensor LPG: No Oxygen sensor
ECT-ECM:	Engine Coolant Temperature Sensor for ECM	
ECT-GAUGE	Engine Coolant Temp. Sensor for GAUGE on Instrument Panel	
TPS:	Throttle Position Sensor (built in Throttle Body)	
THROTTLE BODY:	Electronic Throttle Body	
LP FUEL LOCK-OFF:	12 V operation volt	
ENGINE OIL PR. S/W:	28.4 kPa (4.1 psi)	
STARTING MOTOR:	12 Volts, 1.7 kW	
ALTERNATOR:	13.5 Volts, 90 Amp	
EXHAUST SYSTEM		
Muffler	Catalytic Muffler	Muffler (without catalyst)

Engine Power and Torque

G420FE Engine Power & Torque

FORKLIFT MODEL		G(C)15/18S-5	G(C)20/25/30E-5	
ENGINE MODEL		G420FE-LP	G420FE-DF(LP) & G420FE-LP	G420FE-DF(Gas)
RATED POWER	Kw	33.6	39.5	39.5
	hp	45	53	53
	PS	46	54	54
	rpm	2,400	2,550	2,550
MAX TORQUE	N-m	147	157	157
	lbf-ft	108	116	116
	kgf-m	15,0	16.0	16.0
	rpm	1600	1600	1600
GOVERNED SPEED	rpm	2450	2600	2600
LOW IDLE	rpm	750	750	750

G420F Engine Power & Torque

FORKLIFT MODEL		G(C)15/18S-5		
ENGINE MODEL		G420F-DF(LP) & G420F-LP	G420F-DF(Gas)	G420F-GAS
RATED POWER	Kw	33.6	35.8	36.5
	hp	45	48	49
	PS	45.6	48.7	49.7
	rpm	2,400	2,400	2,400
MAX TORQUE	N-m	147	152	154
	lbf-ft	108	112	114
	kgf-m	15,0	15.5	15.7
	rpm	1600	1600	1600
GOVERNED SPEED	rpm	2450	2450	2450
LOW IDLE	rpm	750	750	750

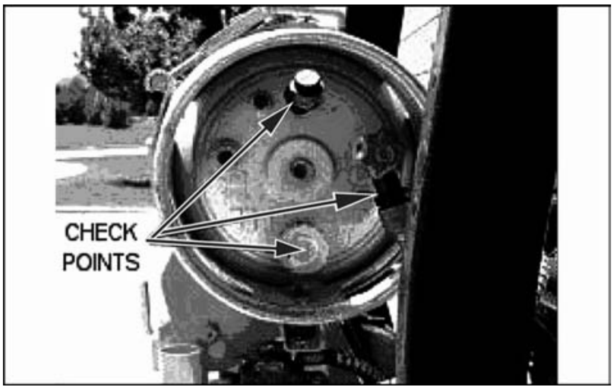
FORKLIFT MODEL		G(C)20/25/30E-5		
ENGINE MODEL		G420F-DF(LP) & G420F-LP	G420F-DF(Gas)	G420F-GAS
RATED POWER	Kw	39.5	39.5	40.3
	hp	53	53	54
	PS	53.7	53.7	54.7
	rpm	2,550	2,550	2,550
MAX TORQUE	N-m	157	157	160
	lbf-ft	116	116	118
	kgf-m	16.0	16.0	16.3
	rpm	1600	1600	1600
GOVERNED SPEED	rpm	2600	2600	2600
LOW IDLE	rpm	750	750	750

Chapter 2. RECOMMENDED MAINTENANCE

Suggested maintenance requirements for an engine equipped with an MI-07 fuel system are contained in this section. The operator should, however, develop a customized maintenance schedule using the requirements listed in this section and any other requirements listed by the engine manufacturer.

General Maintenance

Test Fuel System for Leaks



- Obtain a leak check squirt bottle or pump spray bottle.
- Fill the bottle with an approved leak check solution.
- Spray a generous amount of the solution on the fuel system fuel lines and connections, starting at the storage container.
- Wait approximately 15-60 seconds, then perform a visual inspection of the fuel system. Leaks will cause the solution to bubble.
- Listen for leaks
- Smell for LPG odor which may indicate a leak
- Repair any leaks before continuing.
- Crank the engine through several revolutions. This will energize the fuel lock-off and allow fuel to flow to the pressure regulator/converter. Apply additional leak check solution to the regulator/ converter fuel connections and housing. Repeat leak inspection as listed above.
- Repair any fuel leaks before continuing.

Inspect Engine for Fluid Leaks

- Start the engine and allow it to reach operating temperatures.
- Turn the engine off.
- Inspect the entire engine for oil and/or coolant leaks.
- Repair as necessary before continuing.

Inspect Vacuum Lines and Fittings

- Visually inspect vacuum lines and fittings for physical damage such as brittleness, cracks and kinks. Repair/replace as required.
- Solvent or oil damage may cause vacuum lines to become soft, resulting in a collapsed line while the engine is running.
- If abnormally soft lines are detected, replace as necessary.

Inspect Electrical System

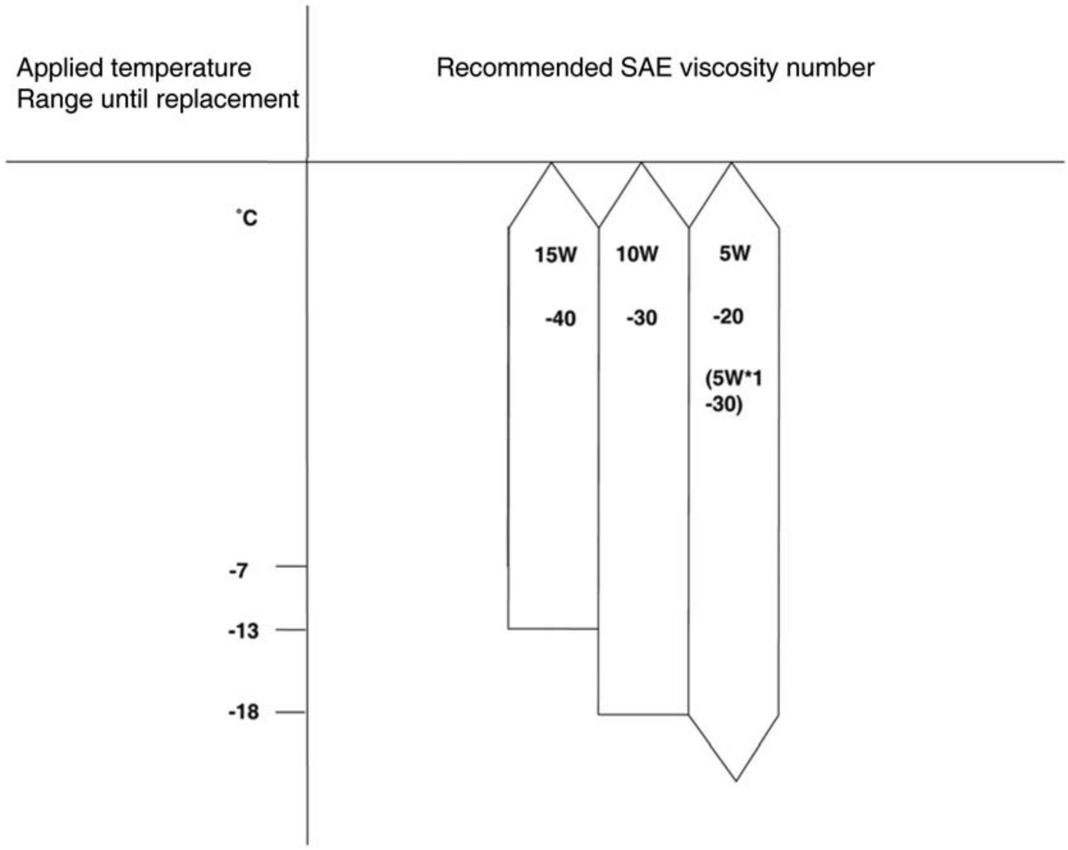
- Check for loose, dirty or damaged connectors and wires on the harness including: fuel lock-off, TMAP sensor, O2 sensors, electronic throttle, control relays, fuel trim valves, crank position sensor, and cam position sensor.
- Repair and/or replace as necessary.

Inspect Foot Pedal Operation

- Verify foot pedal travel is smooth without sticking.

Engine Oil Classification

Recommended API classification: Above SJ
Recommended SAE viscosity classification



*1. 10W-30 engine oil is recommended
If 10W-30 is not applicable, proper engine oil will be possible according to temperature ranges.

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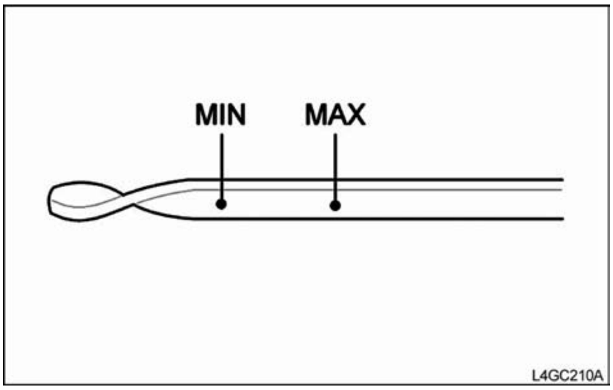
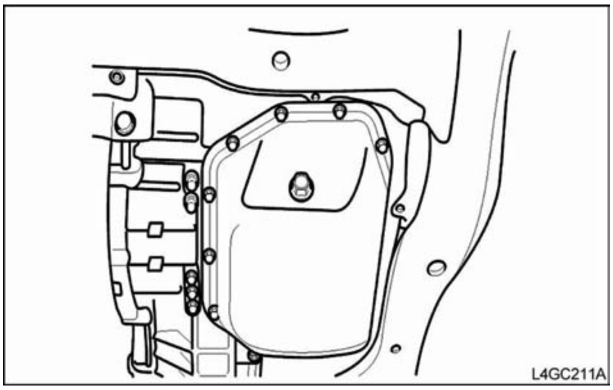
The following lubricants should be selected for all engines to enhance excellent performance and maximum effect.

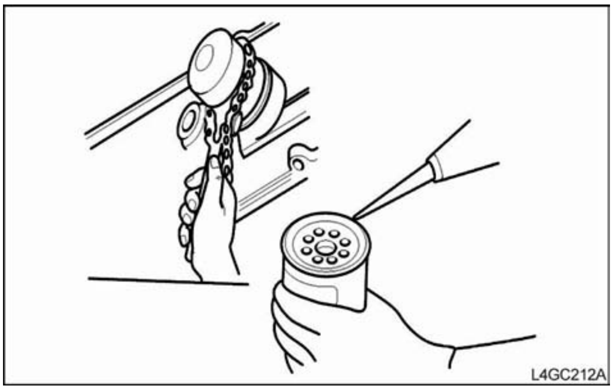
1. Observe the API classification guide.

2. Proper SAE classification number should be selected within ambient temperature ranges. Do not use the lubricant with SAE classification number and API grade not identified on the container.

Checking Engine Oil Level







1. Check that the oil level is between "MIN" and "Max" marks on the engine oil level gauge.

2. If the oil level is below "MIN" mark, add oil until the level is within the specified ranges.

3. Check the engine for oil contamination and viscosity and replace if necessary.

Replacing Engine Oil and Filter

⚠ CAUTION

Prolonged and repeated contact with mineral oil will result in the removal of natural fats from the skin, leading to dryness, irritation and dermatitis. In addition, used engine oil contains potentially harmful contaminants which may cause skin cancer.
Exercise caution in order to minimize the length and frequency of contact of your skin to used oil. In order to preserve the environment, used oil and used oil filter must be disposed of only at designated disposal sites.

1. Drain engine oil.

1) Remove the oil filler cap.

2) Remove the oil drain plug, and drain the oil into a container.

2. Replace oil filter.

1) Remove the oil filter.

2) Check and clean the oil filter installation surface.

3) Check the part number of the new oil filter is as same as old one.

4) Apply clean engine oil to the gasket of a new oil filter.

5) Lightly screw the oil filter into place, and tighten it until the gasket contacts the seat.

6) Tighten it an additional 3/4 turn.

3. Refill with engine oil filter.

1) Clean and install the oil drain plug with a new gasket.

Torque	39.2~44.1N.m(4.0~4.5kgf.m, 28.9~32.5lb-ft)

2)Fill with fresh engine oil.

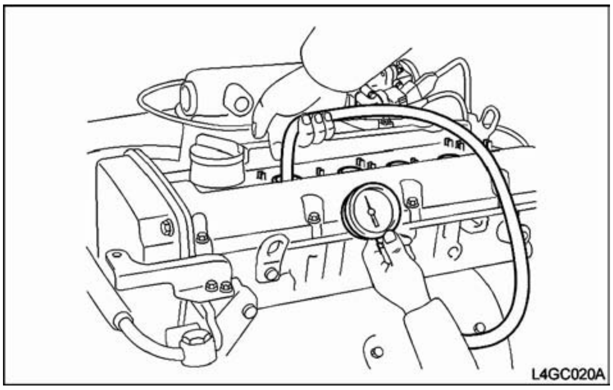
Capacity Drain and refill	4.0L(4.23US qts, 3.52Lmp qts)
Oil filter	0.3L(0.32US qts, 0.26Lmp qts)

3) Install the oil filler cap.

4. Start engine and check for oil leaks.

5. Recheck engine oil level.

Checking Compressed Pressure



1. Prior to inspection, check that the engine oil, starter motor and battery are normal.

2. Start the engine and run it until the engine coolant temperature reaches 80 ~ 95°C.

3. Stop the engine and disconnect the ignition coil and air cleaner element.

4. Remove the spark plug.

5. After opening the throttle valve completely, crank the engine to remove foreign material from the cylinder.

⚠ CAUTION

At this time, necessarily screen the spark plug hole with a rag. Because hot coolant, oil, fuel, and other foreign material, being penetrated in the cylinder through cracks can come into the spark hole during checking compressed pressure.
When cranking the engine to test compressed pressure, necessarily open the throttle valve be-fore cranking.

6. Install the compression gauge to the spark plug hole.

7. With the throttle valve opened, crank the engine to measure the compressed pressure.

Standard(250~400rpm)	Standard	15kg/㎠
	Limit	14kg/㎠

8. Follow the procedures (no.6-7) to each cylinder and check that compressed pressure values of all cylinders are within the limit.

Limit	1.0kg/㎠

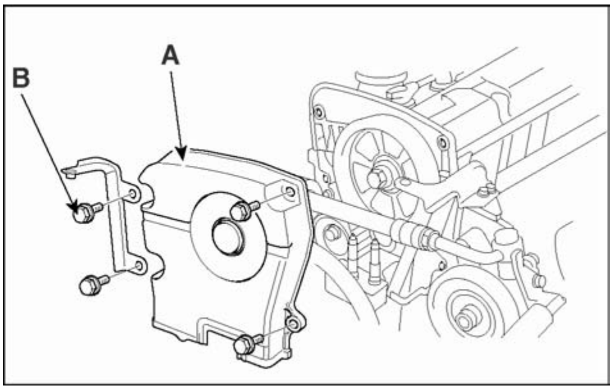
9. If any of all cylinders is out of limit, add a small amount of engine oil to the spark plug hole, and re-proceed the procedures (no.6-7) to the cylinder.

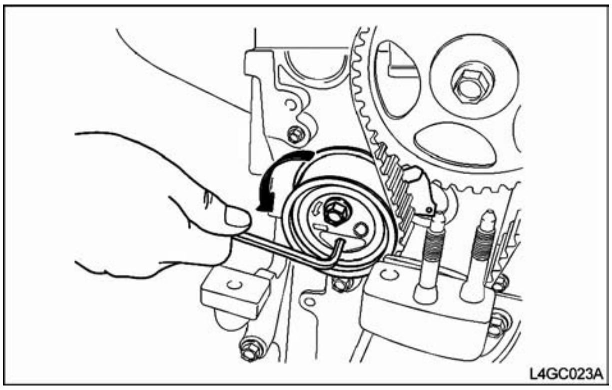
At this time, if the compressed pressure is increased, it means that the piston, piston ring or cylinder surface are worn or damaged, and if the compressed pressure is decreased, it means that the valve is clogged, the valve contact is faulty, or the pressure leaks through gasket.

⚠ CAUTION

If a large amount of incomplete combustion gaso-line comes into the catalytic converter, emergency such as a fire can occur due to overheating. So this job should be done quickly with the engine not operated.

Adjusting Timing Belt Tension





Adjust the tension as the following order.

1. Remove the fan drive bracket.

2. Loosen the timing belt upper cover bolt (B) and disconnect the upper cover (A).

3. As the illustration, insert the hex wrench to the adjuster groove and turn it counterclockwise to move the arm indi-cator in the middle of the base groove.

⚠ CAUTION

If it is turned in reverse direction, be sure that the tensioner may function abnormally.

4. Tighten the tensioner fixing bolt with the arm indicator fixed.

Tightening torque	2.3~2.9kgf·m

5. Rotate the crankshaft 2 turns clockwise and make sure the auto tensioner arm indicator is placed in the middle of the base groove.

6. If the arm indicator is out of the middle, loosen the bolt and repeat the previous procedure.

7. Install the timing belt upper cover (A) and tighten the bolt(B).

Tightening torque	0.8~1.0kg·m

Cooling System Maintenance

Coolant Recommendation

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ CAUTION

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

Coolant Water
Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (pps)
Chlorides (CI)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Antifreeze
DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Check Coolant Level

- The items below are a general guideline for system checks. Refer to the engine manufacturer's specific recommendations for proper procedures.
- Engine must be off and cold.

⚠ WARNING—PROPER USE

Never remove the pressure cap on a hot engine.

- The coolant level should be equal to the "COLD" mark on the coolant recovery tank.

- Add approve coolant to the specified level if the system is low.

Inspect Coolant Hoses

- Visually inspect coolant hoses and clamps. Remember to check the two coolant lines that connect to the pressure regulator/converter.

- Replace any hose that shows signs of leakage, swelling, cracking, abrasion or deterioration.

Checking coolant leaks

1. After the coolant temperature drops below 38°C loosen the radiator cap.

2. Check that the coolant level reaches filler neck.

3. Install the radiator cap tester to the radiator filler neck and apply a pressure of 1.4kg/cm2 .
While maintaining it for 2 minutes, check the radiator, hose, and connecting part for leak.

⚠ CAUTION

Because the coolant in the radiator is too hot, never open the cap when it hot, or injury may occur due to an outburst of hot water.
Dry out the inspection part.
When removing the tester, take care not to spill the coolant.
When removing/installing the tester as well as testing, take care not to deform the filler neck.

4. Replace parts if leak is detected.

Specific gravity test

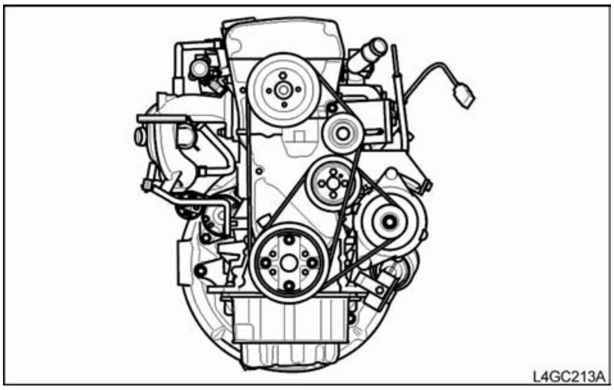
1. Measure specific gravity of the coolant using a hydrometer.

2. After measuring the coolant temperature, calculate specific gravity using the following table.

Relation between Coolant concentration and Specific Gravity

Temperature and Specifiv gravity of coolant (Temp.:℃)					Freezing temp(℃)	Coolant Concentration (Specific Volume)
10	20	30	40	50		
1.054	1.050	1.046	1.042	1.036	-16	30%
1.063	1.058	1.054	1.049	1.044	-20	35%
1.071	1.067	1.062	1.057	1.052	-25	40%
1.079	1.074	1.069	1.064	1.058	-30	45%
1.087	1.082	1.076	1.070	1.064	-36	50%
1.095	1.090	1.084	1.077	1.070	-42	55%
1.103	1.098	1.092	1.084	1.076	-50	60%

Checking and Adjusting Drive Belt



1. Checking tension

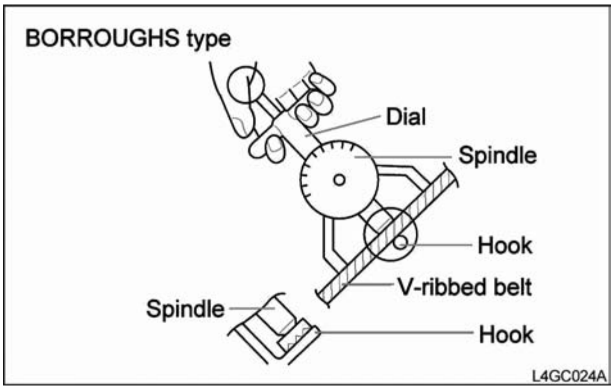
1) Press the middle of the water pump pulley and alternator pulley with 10kgf.

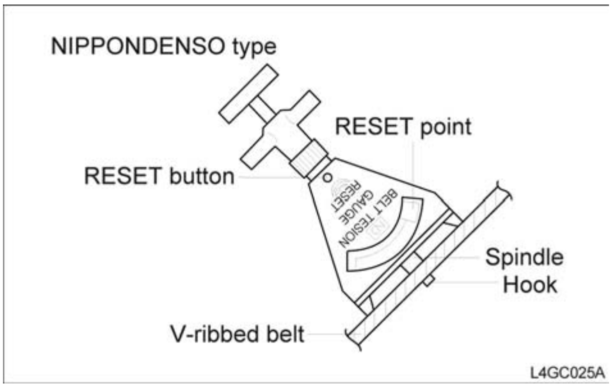
2) Inspect the belt deflection by pressing it.

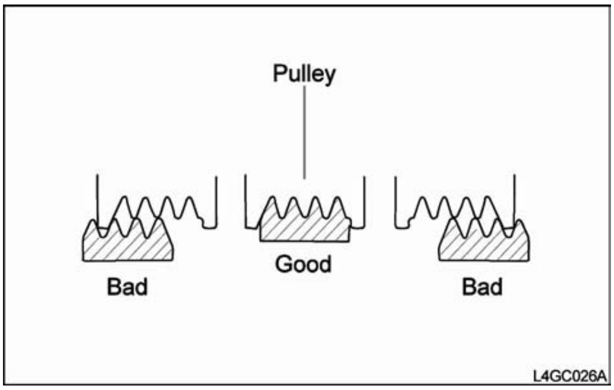
3) If the belt deflection is out of the standard, adjust it as follows.

Item	Standard	
	New belt	Used belt
Drive belt deflection (L)	4.0~4.4mm	5.1~5.7mm

2. Using a tension gauge







1) Type

• BORROUGHS BT - 33 - 73F

• NIPPONDENSO BTG – 2

2) How to use

• Insert the belt between the gauge hook and spindle and press the tension gauge handle.

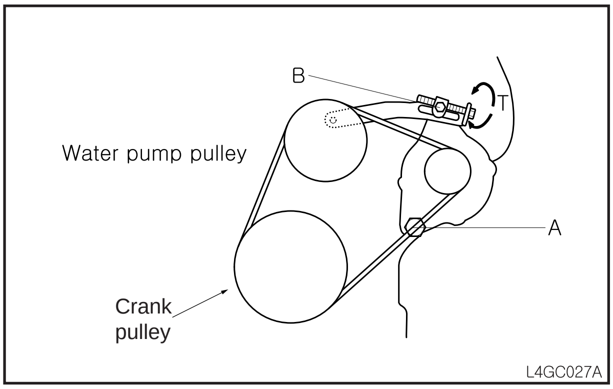
• Leave the handle and read the gauge.

Tension(T)	Standard	
	New belt	Used belt
	65~75kg	40~50kg

⚠ CAUTION

The belt used over 5 minutes should be adjusted as used belt of standard
Check that the belt is installed correctly.
When the belt is loosened, slip noise is heard.

Adjusting



1. Loosen the alternator support bolt “A” nut and adjusting lock bolt “B”.

2. Adjust the belt tension by moving the alternator brace adjusting bolt to “T” direction.

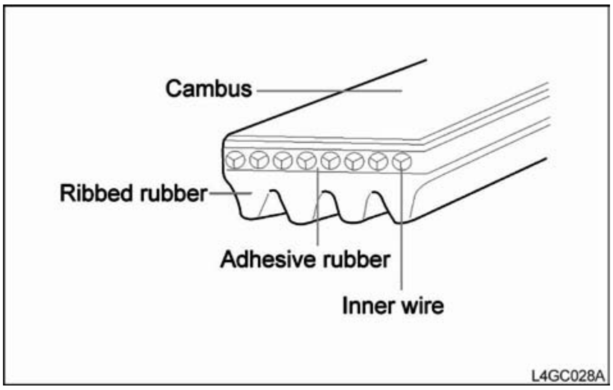
Alternator adjusting lock bolt “B”	1.2~1.5kg·m
Alternator support bolt “A”	2~2.5kg·m

3. Tighten the bolt “A” and then tighten “B” to the specified torque.

⚠ CAUTION

If the belt tension is too excessive, noise as well as early wear of belt occurs and the water pump bearing and alternator bearing are damaged.
If the belt is too loose, due to early wear of belt and insufficient power of alternator, battery and water pump become inefficient and finally engine is overheated or damaged.

Checking Belt for Damage



Check the following items and replace the belt if defective.

1. Check the belt surface for damage, wear and crack.

2. Check the belt surface for oil or grease contamination.

3. Check the rubber part for wear or hardening.

4. Check the pulley surface for crack or damage.

Ignition System Maintenance

Inspect Battery System

- Clean battery outer surfaces with a mixture of baking soda and water.
- Inspect battery outer surfaces for damage and replace as necessary.
- Remove battery cables and clean, repair and/or replace as necessary.

Inspect Ignition System

- Remove and inspect the spark plugs. Replace as required.
- Inspect the ignition coil for cracks and heat deterioration. Visually inspect the coil heat sink fins. If any fins are broken replace as required.

Inspection of Ignition Timing

1. Inspection condition

Coolant temperature : 80-90°C(At normal Temperature)

Lamp and all accessories : OFF

Transmission : In neutral position

Parking brake : ON

2. Inspection

1) Connect the timing light.

2) Measure RPM.

RPM

Low Idle	750±15rpm

NOTE: If RPM is not normal, it is impossible to measure the proper ignition timing, so measure it at a normal RPM.

3) Inspect the standard ignition timing.

BTDC	5˚±5˚

4) If ignition timing is out of the standard, inspect sensors concerned with ignition timing.

⚠ CAUTION

Because ignition timing is fixed by set data value in ECU, it is impossible to control on purpose.
Fist, check that sensors send output properly to help determine ignition timing control.

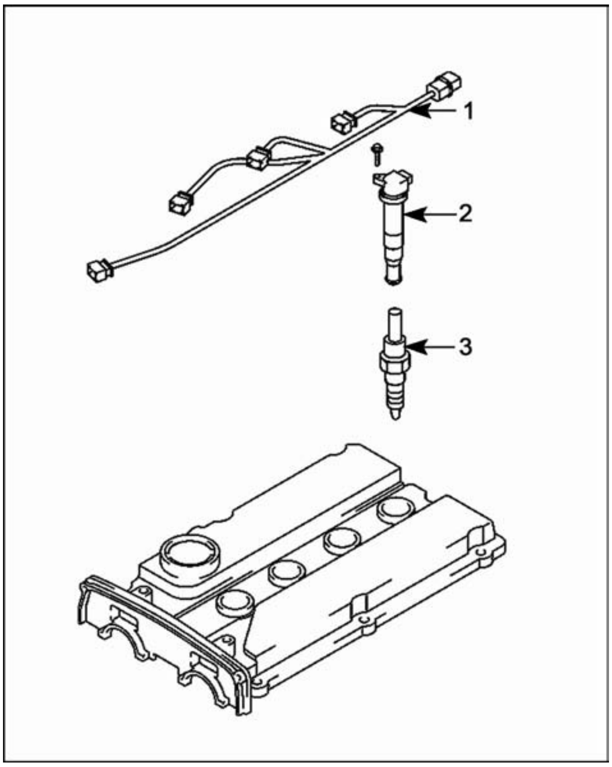
NOTE: Affective ECU input to Ignition timing control

- Coolant temperature sensor
- Oxygen sensor
- Battery voltage
- MAP sensor (Engine load)
- Crankshaft position sensor
- Throttle position sensor
- Intake Air Temperature sensor

5) Check that actual ignition timing is changed with engine RPM increased.

Inspection of Spark Plug

Inspection and clean



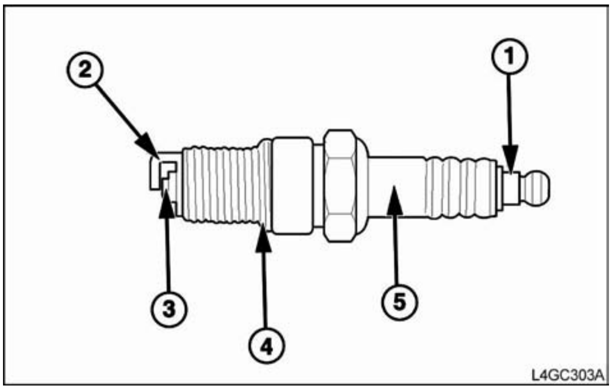
1) Ignition wire Ass'y
2) Ignition coil Ass'y
3) Spark plug

1. Disconnect the ignition wire ass'y from ignition coil ass'y.
Remove the ignition coil ass'y by pulling the ignition coil hand.

2. Remove all spark plugs from the cylinder head using a sparkplug wrench.

⚠ CAUTION

Take care not to come foreign materials into spark-plug mounting hole.



3. Check the spark plug as below.

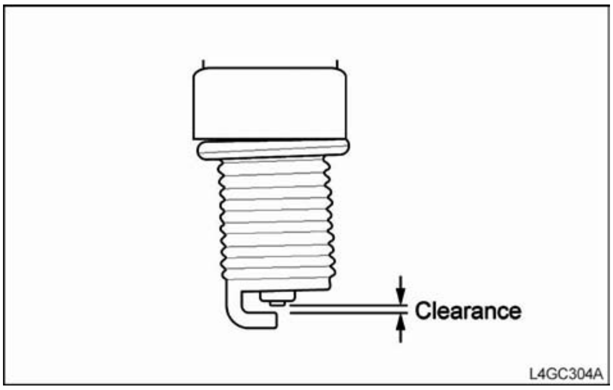
1) Insulator broken

2) Terminal worn

3) Carbon deposit

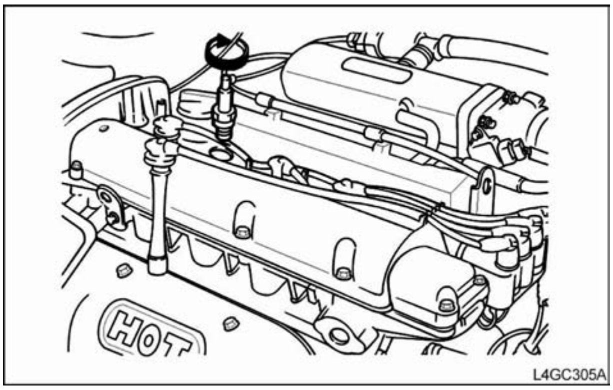
4) Gasket damaged or broken

5) Porcelain insulator of spark plug clearance



4. Check the plug clearance using a plug clearance gauge and if the value is not within the specified values, adjust it by bending the ground clearance. When installing a new sparkplug, install it after checking the uniform plug clearance.

Spark plug clearance	0.7~0.8mm



5. Install the spark plug and tighten it to the specified torque.

Take care not to over tighten it to prevent cylinder head threads from damage.

Tightening torque	2~3kg·m

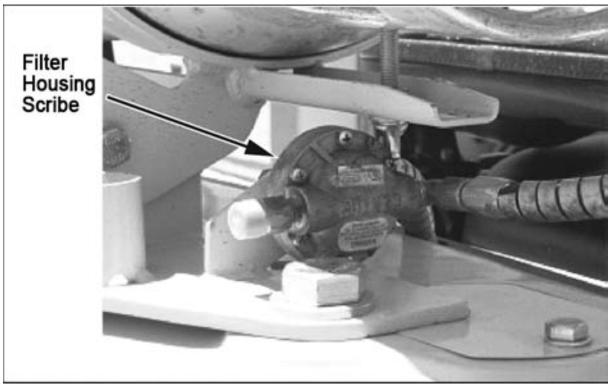
SPARK PLUG ANALYSIS

State	Contact point is black	Contact point is white
Description	• Density of the fuel mixture is thick • Lack of air intake	• Density of the fuel mixture is thin • Ignition timing is fast • Spark plug is tight • Lack of torque

Fuel System Maintenance

Replace LP Fuel Filter Element

Park the lift truck in an authorized refueling area with the forks lowered, parking brake applied and the transmission in Neutral.

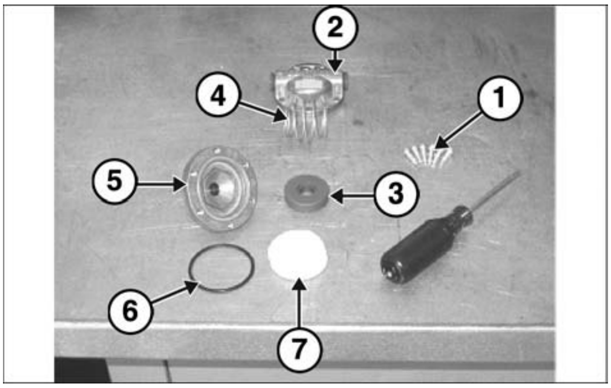


1. Close the fuel shutoff valve on the LP-fuel tank. Run the engine until the fuel in the system runs out and the engine stops.

2. Turn off the ignition switch.

3. Scribe a line across the filter housing covers, which will be used for alignment purposes when re-installing the filter cover.

FUEL FILTER DISASSEMBLY (Steps 4-7)



4. Remove the cover retaining screws (1).

5. Remove top cover (2), magnet (3), spring (4), and filter element (7) from bottom cover (5).

6. Replace the filter element (7).

7. Check bottom cover O-ring seal (6) for damage. Replace if necessary.

8. Re-assemble the filter assembly aligning the scribe lines on the top and bottom covers.

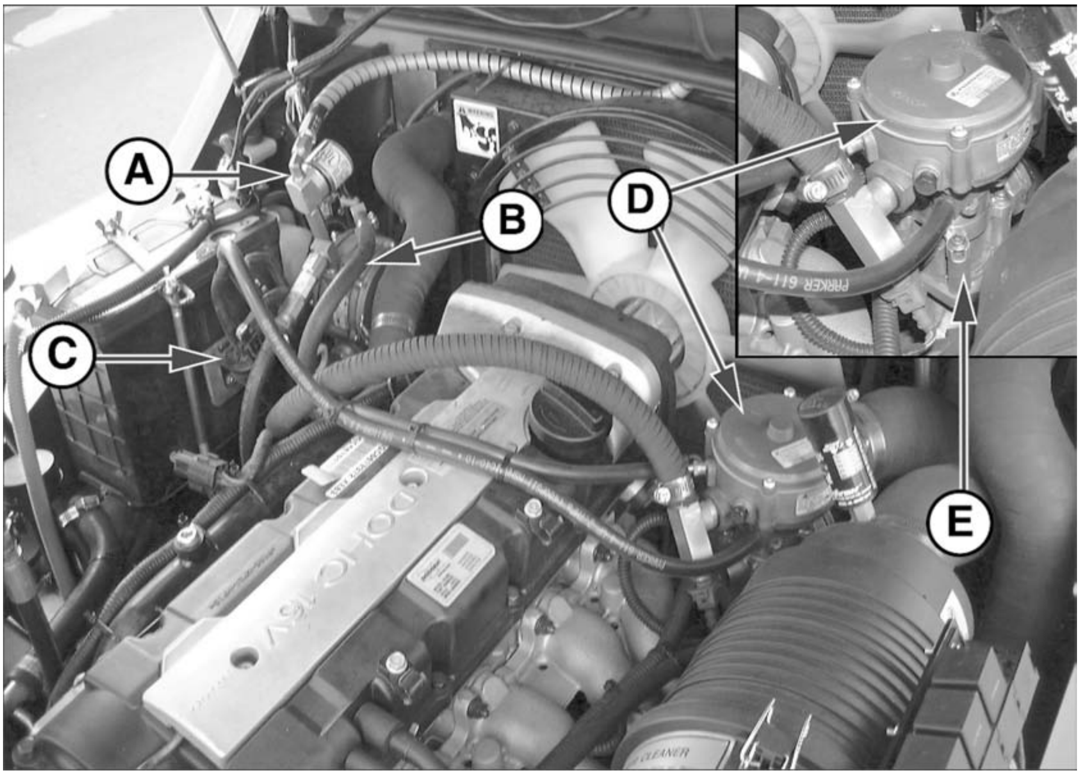
9. Install the cover retaining screws, tightening the screws in an opposite sequence across the cover.

10. Open the fuel valve by slowly turning the valve counterclockwise.

11. Crank the engine several revolutions to open the fuel lock-off. DO NOT START THE ENGINE. Turn the ignition key switch to the off position.

12. Check the filter housing, fuel lines and fittings for leaks. Repair as necessary.

Testing Fuel Lock-off Operation



- Start engine.
- Locate the electrical connector for the fuel lock (A).
- Disconnect the electrical connector.
- The engine should run out of fuel and stop within a short period of time.

NOTE

The length of time the engine runs on trapped fuel vapor increases with any increase in distance between the fuel lock-off and the pressure regulator/converter.

- Turn the ignition key switch off and re-connect the fuel lock-off connector.

Pressure Regulator/Converter Inspection

- Visually inspect the pressure regulator/converter (B) housing for coolant leaks.
- Refer to Chapter 5 if the pressure regulator/converter requires replacement.

Fuel Trim Valve Inspection (FTV)

- Visually inspect the fuel trim valves (C) for abrasions or cracking. Replace as necessary.
- To ensure a valve is not leaking a blow-by test can be performed.

1. With the engine off, disconnect the electrical connector to the FTVs.

2. Disconnect the vacuum line from the FTVs to the pressure regulator/converter at the converter's tee connection.

3. Lightly blow through the vacuum line connected to the FTVs.
Air should not pass through the FTVs when de-energized.

If air leaks past the FTVs when de-energized, replace the FTVs.

Inspect Air/Fuel Valve Mixer Assembly

- Refer to Chapter 5 for procedures regarding the LP mixer (D).

Inspect for Intake Leaks

- Visually inspect the intake throttle assembly (E), and intake manifold for looseness and leaks. Repair as necessary.

Inspect Throttle Assembly

- Visually inspect the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips. Repair and/or replace as necessary.

NOTE: Refer to Chapter 5 for procedures on removing the mixer and inspecting the throttle plate.

Checking the TMAP Sensor

- Verify that the TMAP sensor (F) is mounted tightly into the manifold or manifold adapter (E), with no leakage.

- If the TMAP is found to be loose, remove the TMAP retaining screw and the TMAP sensor from the manifold adapter.

- Visually inspect the TMAP O-ring seal for damage. Replace as necessary.

- Apply a thin coat of an approved silicon lubricant to the TMAP O-ring seal.

- Re-install the TMAP sensor into the manifold or manifold adapter and securely tighten the retaining screw.

Exhaust System Maintenance

Inspect Engine for Exhaust Leaks

- Start the engine and allow it to reach operating temperatures.

- Perform visual inspection of exhaust system from the engine all the way to the tailpipe. Any leaks, even after the post-catalyst oxygen sensor, can cause the sensor output to be effected (due to exhaust pulsation entraining air upstream). Repair any/all leaks found. Ensure the length from the post-catalyst sensor to tailpipe is the same as original factory.

- Ensure that wire routing for the oxygen sensors is still keeping wires away from the exhaust system. Visually inspect the oxygen sensors to detect any damage.

Maintenance Schedule

NOTE: The MI-07 fuel system was designed for use with LPG fuel that complies with HD5 or HD10 LPG fuel standards. Use of non-compliant LPG fuel may require more frequent service intervals and will disqualify the user from warranty claims.

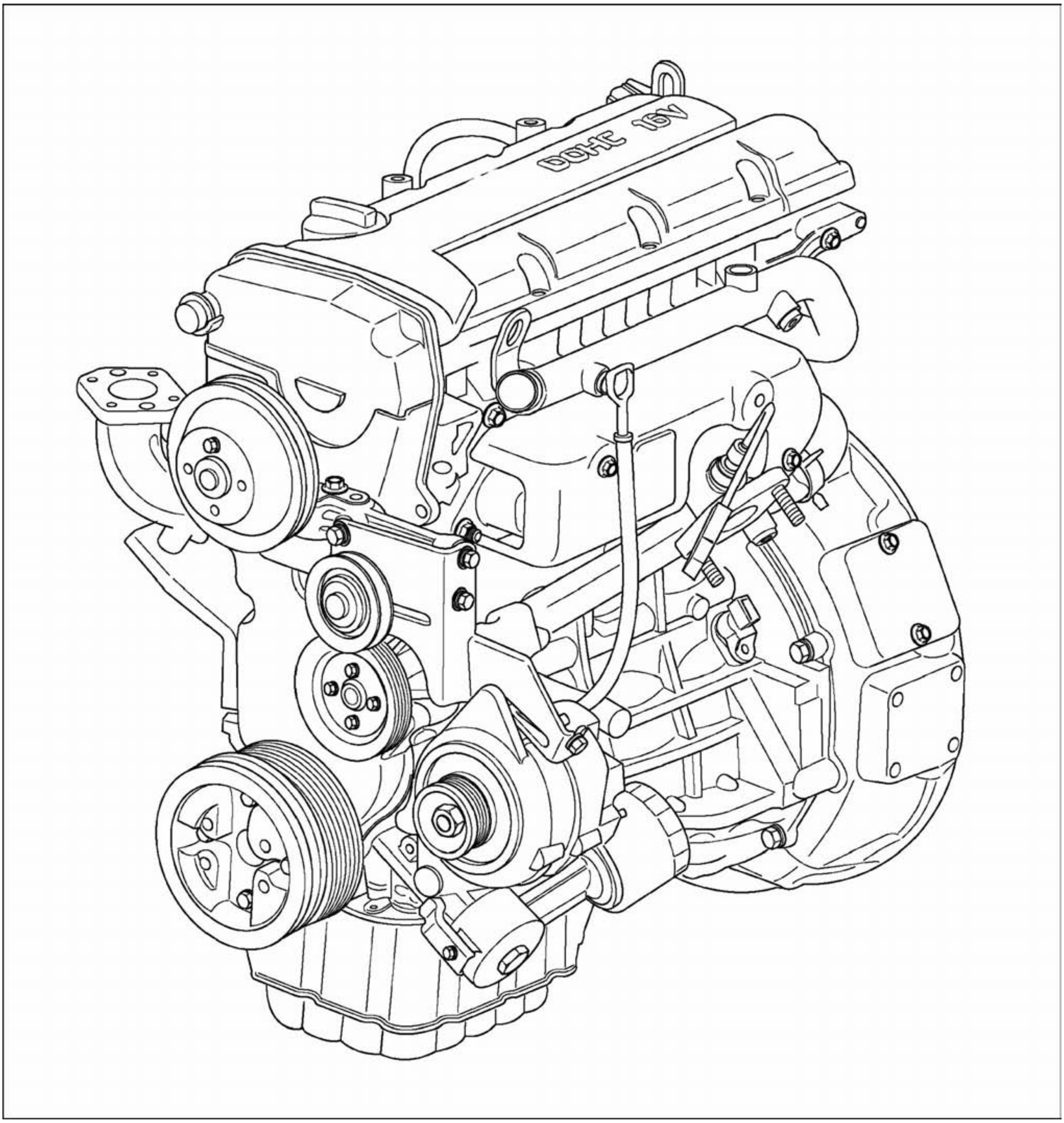
CHECK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 months	Every 1000 Hours or 6 months	Every 1500 Hours or 9 months	Every 2500 Hours or 15 months	Every 3000 Hours or 18 months
General Maintenance							
Test fuel system for leaks.	Prior to any service or maintenance activity						
Inspect engine for fluid leaks.	X						
Inspect all vacuum lines and fittings.			X				
Inspect electrical system; check for loose, dirty, or damaged wires and connections.			X				
Inspect isolation mounts on engine control module for cracks and wear; replace as necessary.			X				
Inspect all fuel fittings and hoses.				X			
Inspect foot pedal travel and operation.	X						
Replace timing belt							X
Check for MIL lamp test at key-on. If MIL lamp remains illuminated (indicating a fault), use pedal to recover fault code(s). Repair faults.	X						
Engine Coolant							
Check coolant level.	X						
Inspect coolant hoses and fittings for leaks, cracks, swelling, or deterioration.				X			
Engine Ignition							
Inspect battery for damage and corroded cables.						X	
Inspect ignition system.					X		
Replace spark plugs						X	
Fuel Lock-Off/Filter							
Replace LP fuel filter element.					X		
Inspect lock-off and fuel filter for leaks.				X			
Ensure lock-off stops fuel flow when engine is off.				X			

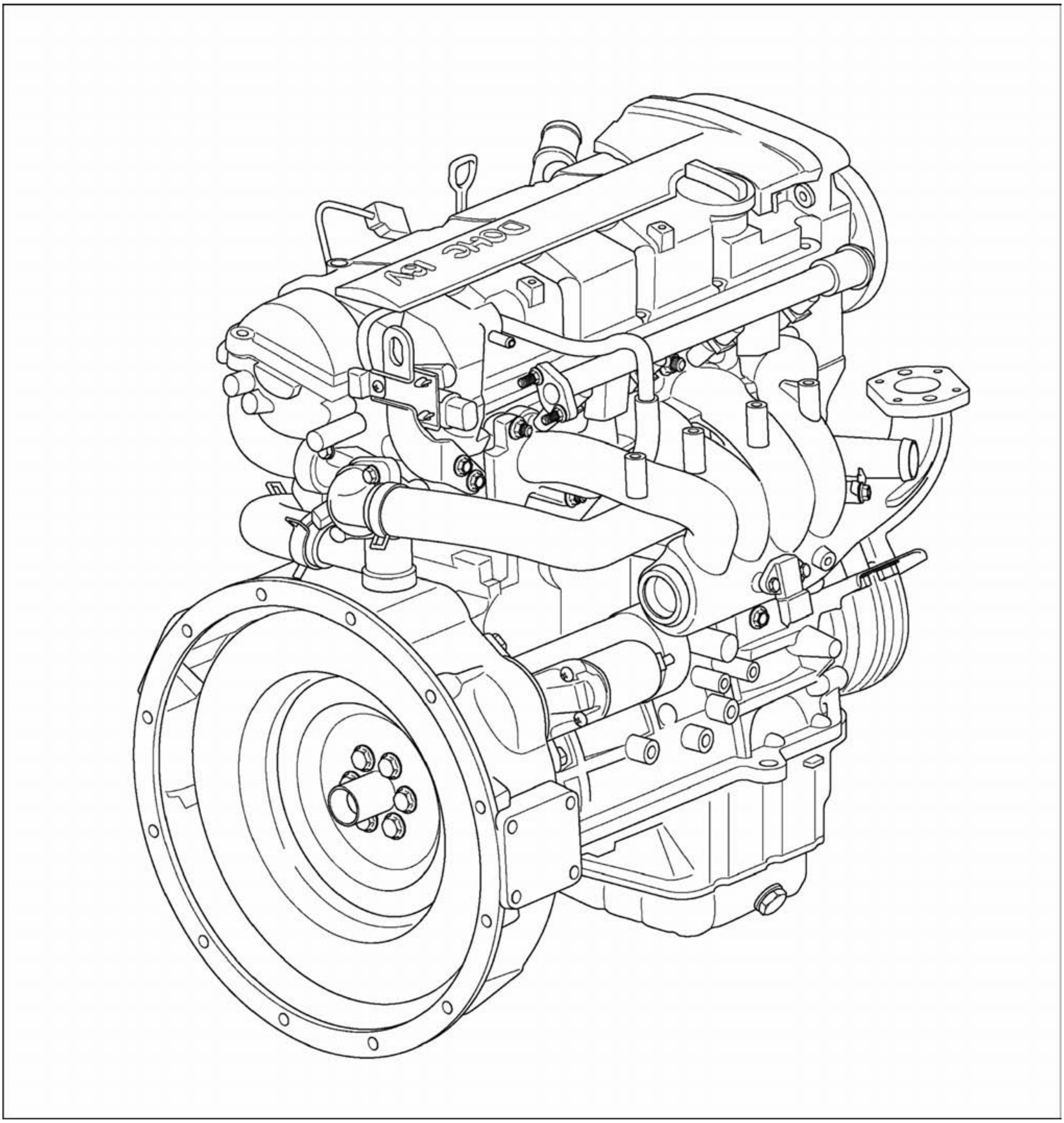
CHECK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 months	Every 1000 Hours or 6 months	Every 1500 Hours or 9 months	Every 2500 Hours or 15 months	Every 3000 Hours or 18 months
Pressure Regulator/Converter							
Test regulator pressures.				X			
Inspect pressure regulator vapor hose for deposit build-up. Clean or replace as necessary.				X			
Inspect regulator assembly for fuel/coolant leaks.				X			
Fuel Trim Valve (G420FE only)							
Inspect valve housing for wear, cracks or deterioration.				X			
Ensure valve seals in the closed position when the engine is off.				X			
Replace FTV.	When indicated by MIL						
Carburetor (Mixer)							
Check air filter indicator.	X						
Check for air leaks in the filter system.				X			
Inspect air/fuel valve mixer assembly for cracks, loose hoses, and fittings. Repair or replace as necessary.			X				
Check for vacuum leaks in the intake system including manifold adapter and mixer to throttle adapter.						X	
Repair or replace throttle assembly.	When indicated by MIL						
Inspect air filter.			X				
Replace air filter element.				X			
Check TMAP sensor for tightness and leaks.						X	
Exhaust & Emission							
Inspect engine for exhaust leaks.	X						
Replace PCV valve and breather element.						X	
Replace HEGO sensors	When indicated by MIL						
Gasoline Engines							
Replace gasoline fuel filter element.						X	
Inspect gasoline fuel system for leaks.						X	
Confirm gasoline supply pressure is correct.	Pressure should be 45-55 psig (310-379 kPa)						

Chapter 3. ENGINE MECHANICAL SYSTEM

General Information

Engine Outline




DOHC 16V

Specifications

Description	Specification	Limit
GENERAL		
Type		
Cylinder number	In-line, DOHC	
Bore	4	
Stroke	82 mm	
Displacement	93.5 mm	
Compression ratio	1,975 cc	
Firing order	1 - 3 - 4 - 2	
Low idle	750±15 rpm	
Ignition timing @ low idle	BTDC 5°±5°	
Valve timing		
Intake		
Open	BTDC 2°	
Close	ABDC 16°	
Exhaust		
Open	BBDC 6°	
Close	ATDC 2°	
Valve over rap	4°	
CYLINDER HEAD		
Flatness of gasket surface	0.03 mm or less	0.06mm
Flatness of manifold mounting surface	0.15 mm or less	0.3mm
Oversize of valve seat hole		
Intake		
0.3 mm OS	33.3 ~ 33.325 mm	0.2mm
0.6 mm OS	33.6 ~ 33.625 mm	
Exhaust		
0.3 mm OS	28.8 ~ 28.821 mm	
0.6 mm OS	29.1 ~ 29.121 mm	
Oversize of valve guide hole		
0.05 mm OS	11.05 ~ 11.068 mm	
0.25 mm OS	11.25 ~ 11.268 mm	
0.50 mm OS	11.50 ~ 11.518 mm	
CAMSHAFT		
Cam height		
Intake	43 mm	
Exhaust	43 mm	
Journal O.D	Ø28 mm	
Bearing oil clearance	0.02 ~ 0.061 mm	
End play	0.1 ~ 0.2 mm	

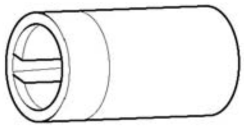
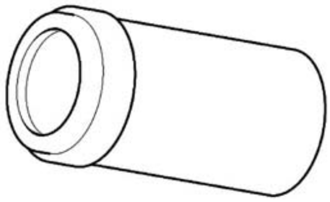
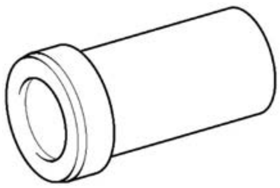
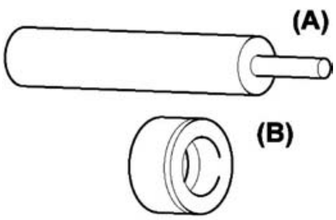
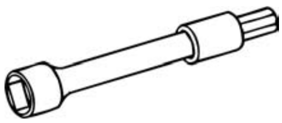
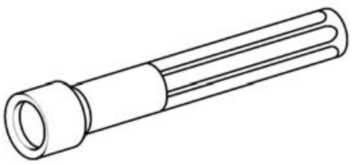
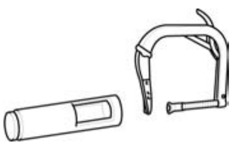
Description	Specification	Limit
VALVE		
Stem O.D		
Intake	5.965 ~ 5.980 mm	
Exhaust	5.950 ~ 5.965 mm	
Thickness of valve head (Margin)		
Intake	1.15 mm	0.8 mm
Exhaust	1.35 mm	1.0 mm
Valve stem to guide clearance		
Intake	0.02 ~ 0.05 mm	0.1 mm
Exhaust	0.035 ~ 0.065 mm	0.13 mm
VALVE GUIDE		
Installed size	Intake : 46, Exhaust : 54.5	
Over size(O.D)	0.05, 0.25, 0.50 mm	
VALVE SEAT		
Seat angle	45°	
Over size	0.3 mm, 0.6 mm	
VALVE SPRING		
Free length	48.86 mm	
Load	18.3kg/39 mm	
	40.0kg/30.5 mm	
Installed height	39 mm	
Out-of squareness	1.5° or less	3°
CYLINDER BLOCK		
Cylinder I.D	82.00 ~ 82.03 mm	
Out-of cylindricity of cylinder I.D	Less than 0.01 mm	
Cylinder block-to-piston clearance	0.02 ~ 0.04 mm	
PISTON		
O.D	81.97 ~ 82.00 mm	
Over size	0.25, 0.50, 0.75, 1.00 mm	
PISTON RING		
Side clearance		
No.1	0.04 ~ 0.08 mm	0.1 mm
No.2	0.03 ~ 0.07mm	0.1 mm
End gap		
No.1	0.23 ~ 0.38 mm	
No.2	0.33 ~ 0.48 mm	1.0 mm
Oil ring side rail	0.2 ~ 0.6 mm	1.0 mm
Over size	0.25, 0.50, 0.75, 1.00 mm	1.0 mm
CONNECTING ROD		
Bend	0.05 mm or less	
Twist	0.10 mm or less	
Side clearance	0.100 ~ 0.250 mm	0.4 mm

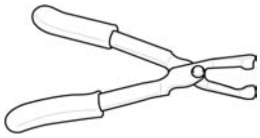
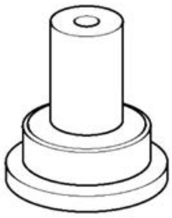
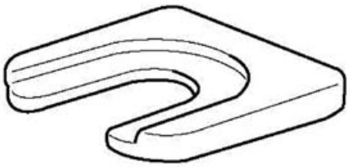
Description	Specification	Limit
CONNECTING ROD BEARING		
Oil clearance	0.024 ~ 0.044 mm	
Under size	0.25, 0.50, 0.75 mm	
CRANKSHAFT		
Pin O.D	45 mm	
Journal O.D	57 mm	
Bend	Less than 0.03 mm	
Out-of cylindricity of journal and pin	Less than 0.01 mm	
End play	0.06 ~ 0.260 mm	
Under size of pin		
0.25 mm	44.725 ~ 44.740 mm	
0.50 mm	44.475 ~ 44.490 mm	
0.75 mm	44.225 ~ 44.240 mm	
Under size of journal		
0.25 mm	56.727 ~ 56.742 mm	
0.50 mm	56.477 ~ 56.492 mm	
0.75 mm	56.227 ~ 56.242 mm	
OIL PUMP		
O.D-to-front case clearance		
Front side clearance	0.12 ~ 0.185 mm	
Tip clearance		
Outer gear	0.025 ~ 0.069 mm	
Inner gear	0.04 ~ 0.09 mm	
Oil pressure (Oil temperature 90°C~100°C)	0.04 ~ 0.085 mm	
at idle (750rpm)	166kpa (1.7kg/cm2)	
RELIEF SPRING		
Free height	43.8 mm	
Load	3.7kg/40.1 mm	
Water pump type	Centrifugal impeller	
THERMOSTAT		
Thermostat type	Wax pellet type with jiggle valve	
Valve open temperature	82°C ± 1.5°C	
Fully open temperature	95°C	
WATER TEMPERATURE SENSOR		
Type	Thermister	
Resistance(at 20°C)	2.31KΩ ~ 2.59KΩ	

Torque Specification

Description	Standard (kg.m)
Cylinder block	
Engine support bracket bolt and nut	3.5 ~ 5.0
Cylinder head	
Cylinder head bolt M10 M12	 2.5+(60°~ 65°) + (60°~ 65°) 3.0+(60°~ 65°) + (60°~ 65°)
Intake manifold bolt and nut	1.6 ~ 2.3
Exhaust manifold nut	4.3 ~ 5.5
Cylinder head cover bolt	0.8 ~ 1.0
Camshaft bearing cap bolt	1.4 ~ 1.5
Rear plate bolt	0.8 ~ 1.0
Main moving	
Connecting rod cap nut	5.0 ~ 5.3
Crankshaft bearing cap bolt	2.7 ~ 3.3+(60°~ 65°)
Flywheel bolt	12.0 ~ 13.0
Chain guide	0.8 ~ 1.0
Starter bolt	2.7 ~ 3.4
Timing belt	
Crankshaft pulley bolt	17 ~ 18
Camshaft sprocket bolt	10 ~ 12
Timing belt tensioner bolt	4.3 ~ 5.5
Timing belt idler bolt	4.3 ~ 5.5
Timing belt cover bolt	0.8 ~ 1.0
Front case bolt	2.0 ~ 2.7
Lubrication System	
Oil filter	1.2 ~ 1.6
Oil pan bolt	1.0 ~ 1.2
Oil pan drain plug	3.5 ~ 4.5
Oil screen bolts	1.5 ~ 2.2
Oil pressure switch	1.3 ~ 1.5
Cooling System	
Thermostat inlet fitting nut	1.5 ~ 2.0
Thermostat housing mounting nut	1.5 ~ 2.0
Water pump mounting bolt	2.0 ~ 2.7
Alternator brace bolt	2.0 ~ 2.7
Coolant temperature sensor	2.0 ~ 4.0
Alternator support bolt and nut	2.0 ~ 2.5
Water pump pulley	0.8 ~ 1.0
Water pipe bracket bolt	1.2 ~ 1.5
Intake and Exhaust System	
Intake manifold to cylinder head bolt	1.6 ~ 2.3
Intake manifold cover to intake manifold bolt	1.8 ~ 2.5
Throttle body and Surge tank nut	1.5 ~ 2.0
Exhaust manifold to cylinder head bolt	4.3 ~ 5.5
Exhaust manifold cover to exhaust manifold bolt	1.5 ~ 2.0
Oxygen sensor to exhaust manifold bolt	5.0 ~ 6.0

Special Tools

Tool (number and name)	Illustration	Use
Crankshaft front oil seal installer (09214-32000)		Installation of front oil seal
Crankshaft front oil seal guide (09214-32100)		Installation of front oil seal
Camshaft oil seal installer (09221-21000)		Installation of camshaft oil seal
Valve guide installer (09221-22000(A/B))		Removal and installation of valve guide
Cylinder head bolt wrench (09221-32001)		Removal and tightening of cylinder head bolt
Valve stem oil seal installer (09222-22001)		Installation of valve stem oil seal
Valve spring compressor holder and adaptor (09222-28000, 09222-28100)		Removal and installation of piston pin (Use with 09234-33003)

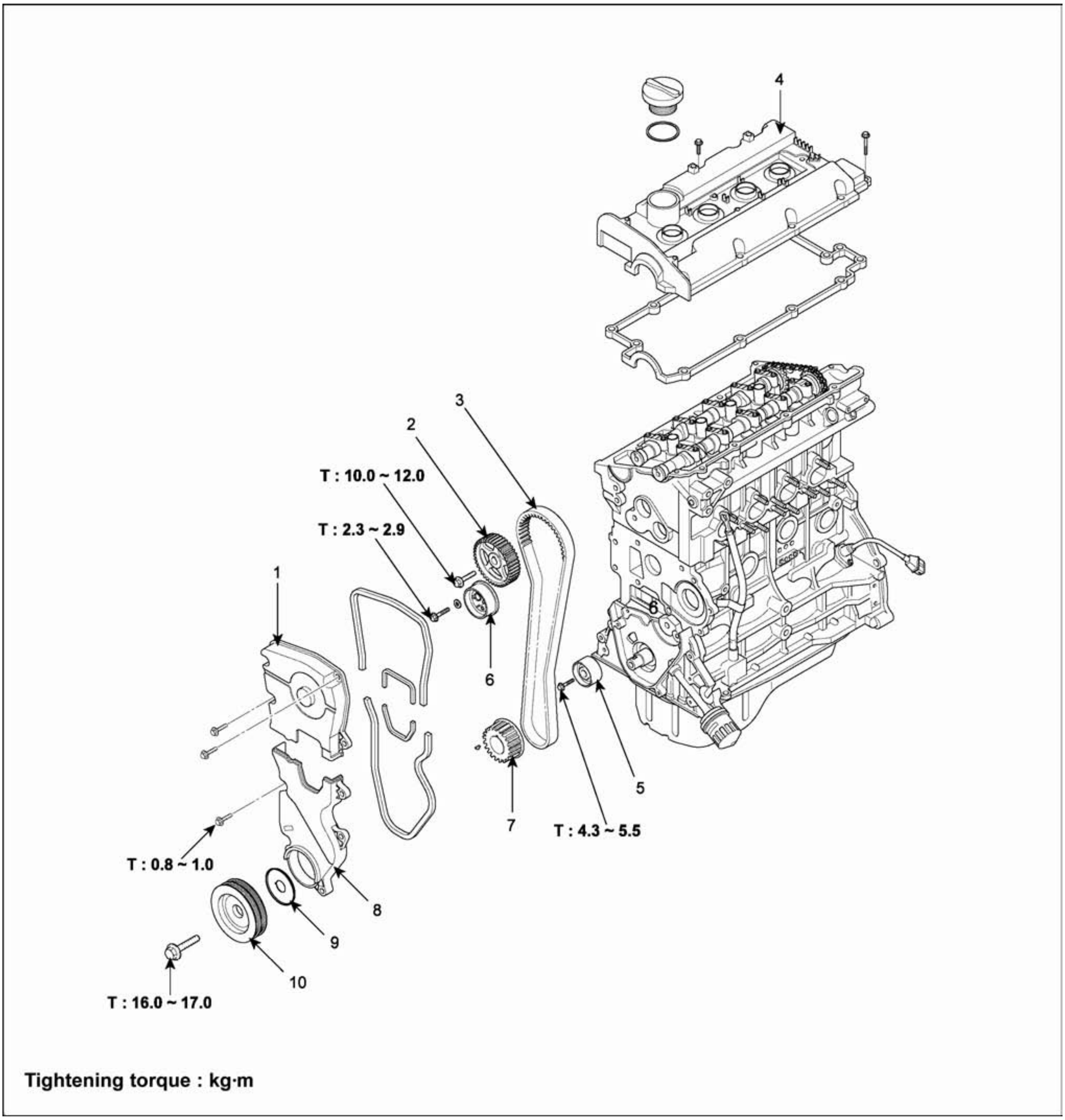
Tool (number and name)	Illustration	Use
Valve stem seal remover (09222-29000)		Removal of valve stem seal
Crankshaft rear oil seal installer (09231-21000)		1. Installation of engine rear oil seal 2. Installation of crankshaft rear oil seal
Piston pin removal and installation kit (09234-33001)		Removal and installation of intake and exhaust valve (Use with 09222-29000)
Piston pin setting tool insert (09234-33002)		Removal and installation of piston pin (Use with 09234-33001)

Troubleshooting

Symptom	Possible cause	Remedy
Low compression	Cylinder head gasket damaged Worn or damaged piston ring Worn piston or cylinder Worn or damaged valve seat	Replace gasket Replace ring Repair or replace piston and cylinder block Repair or replace valve and seat ring
Low oil pressure	Insufficient engine oil Oil pressure switch defective Oil filter clogged Worn oil pump gear or cover Thin or diluted engine oil Oil relief valve clogged(Open) Excessive bearing clearance	Check engine oil level Replace oil pressure switch Install new filter Replace Replace engine oil Replace or inspect Replace bearing
High oil pressure	Oil relief valve clogged(Closed)	Repair relief valve
Noisy valve	Thin or diluted engine oil Faulty HLA Worn belt stem or valve guide	Replace engine oil Replace HLA Replace belt stem or valve guide
Noisy connecting rod or timing belt	Insufficient engine oil Low oil pressure Thin or diluted engine oil Excessive bearing clearance	Check engine oil level Refer to too low oil pressure Replace engine oil Replace bearing
Noisy timing belt	Incorrect belt tension	Correct belt tension
Low coolant level	Coolant leak from Heater or radiator hose Defective radiator cap Thermostat housing Radiator Water pump	Repair or replace parts Retighten clamp or replace Replace gasket or housing Replace Replace parts
Radiator clogged	Foreign material into coolant	Replace coolant
Abnormally high coolant temperature	Thermostat defective Radiator cap defective Abnormal flow in cooling system Loose or missing driving belt Loose water pump Water temperature wiring defective Cooling pan defective Radiator or thermostat switch defective Inefficient coolant	Replace parts Replace parts Clean or replace parts Correct or replace Replace Repair or replace Repair or replace Replace Add coolant
Abnormally low coolant temperature	Thermostat defective Water wiring defective	Replace Repair or replace
Oil cooling system leak	Loose connecting part Cracked or damaged hose, pipe, and oil cooler	Retighten Replace
Exhaust gas leak	Loose connecting part Pipe or muffler damaged	Retighten Repair or replace
Abnormal noise	Breakaway exhaust plate in muffler Rubber hanger damaged Pipe or muffler with body Interfered Pipe or muffler damaged Catalytic converter damaged Each connecting gasket damaged	Replace Replace Repair Repair or replace Replace Replace

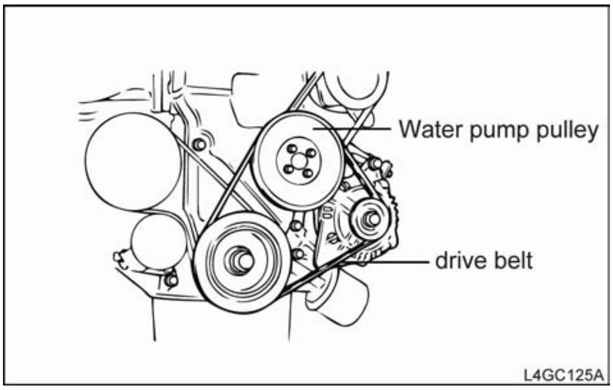
Timing Belt System

Components



1. Timing belt upper cover.
2. Camshaft sprocket
3. Timing belt
4. Cylinder head cover
5. Idler
6. Tensioner
7. Crankshaft sprocket
8. Timing belt lower cover
9. Flange
10. Crankshaft pulley

Removal

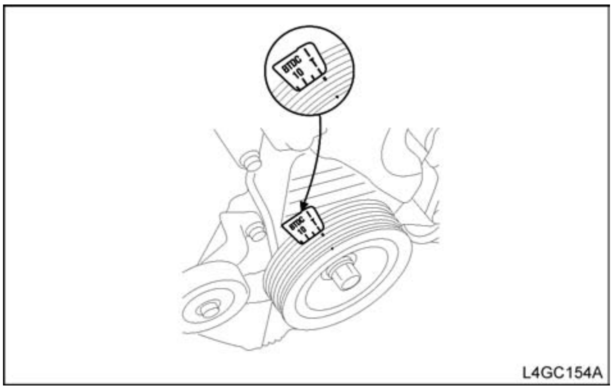


1. Temporarily loosen the water pump pulley bolts.

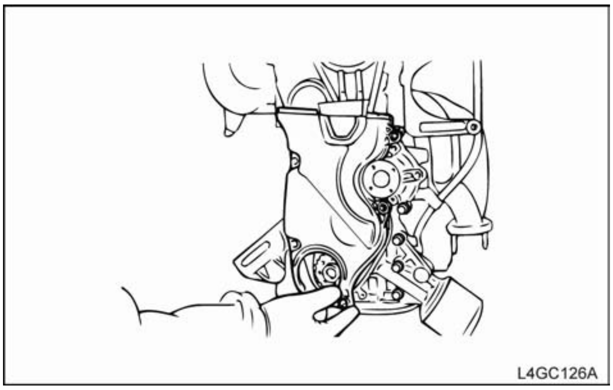
2. Loosen the alternator bolt and remove the belt.

3. Remove the water pump pulley.

4. Remove the timing belt upper cover.



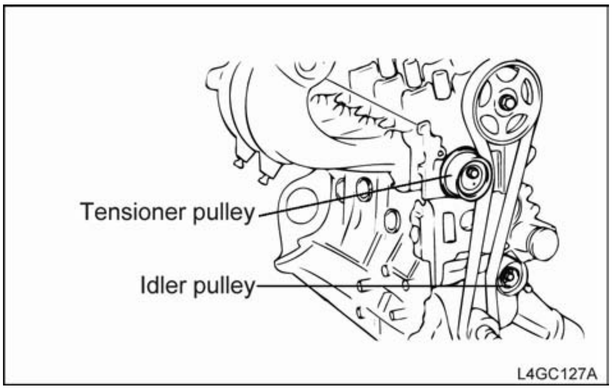
5. Turn the crankshaft, and align its groove with timing mark “T”



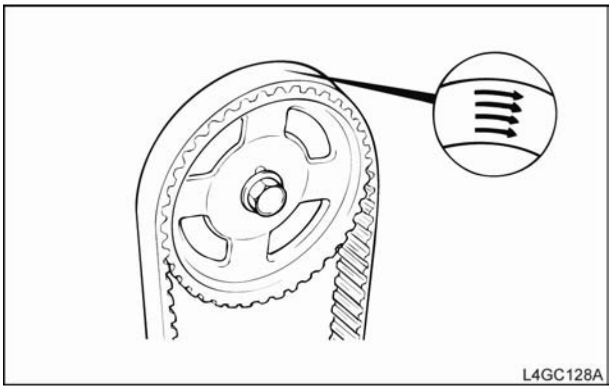
6. Remove the crankshaft pulley.

7. Remove the crankshaft flange.

8. Remove the timing belt lower cover.



9. Remove the timing belt tensioner pulley.



10. Remove the timing belt form the camshaft sprocket.

NOTE: When reusing the timing belt, put an arrow mark on the rotation direction (or front side of engine)before removal to help re-install it to original installation direction.

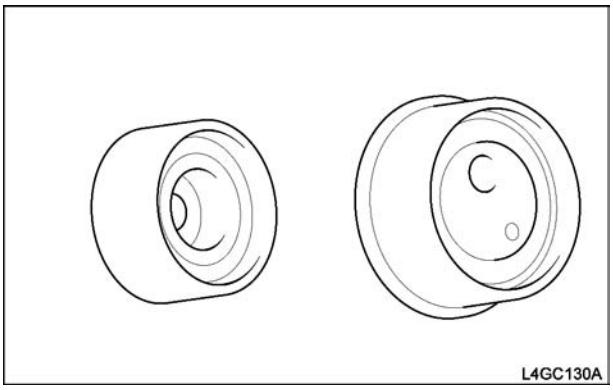
11. Remove the idler.

12. Remove the crankshaft sprocket.

13. Remove the cylinder head cover and remove camshaft sprocket.

Inspection

SPROCKET, TENSIONER, IDLER

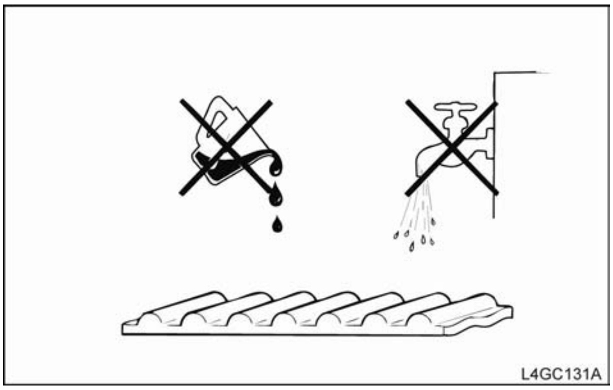


1. Check the camshaft sprocket, crankshaft sprocket, tensioner and idler for wear, crack and damage and replace it if necessary.

2. Check the tensioner and idler pulley for smooth rotation, check for play and noise, and replace it if necessary.

3. If grease leak is inspected, replace it.

TIMING BELT

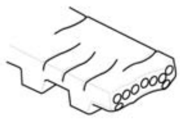
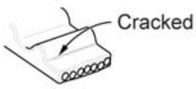
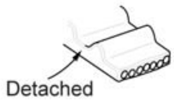
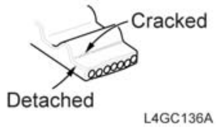
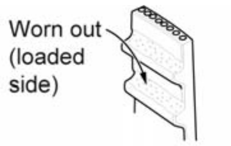
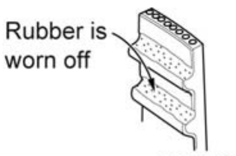
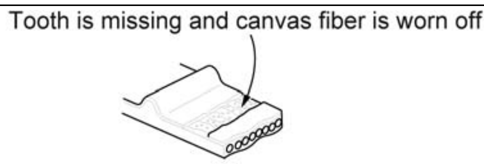
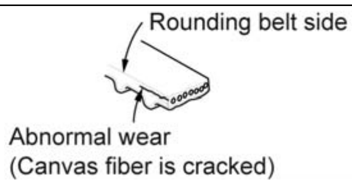
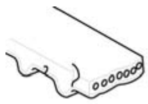


1. Check the belt for oil or dust deposit and replace it if necessary. In case of small amount of oil or dust, clean it with a rag or paper instead of a solvent.

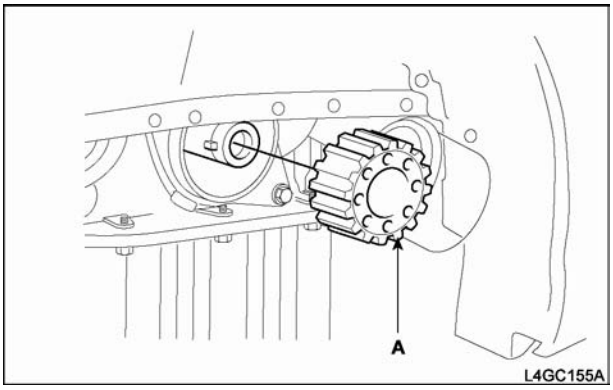
2. After overhauling the engine or readjusting the belt, inspect the belt in detail and replace it with a new one if the following defects are detected.

⚠ CAUTION

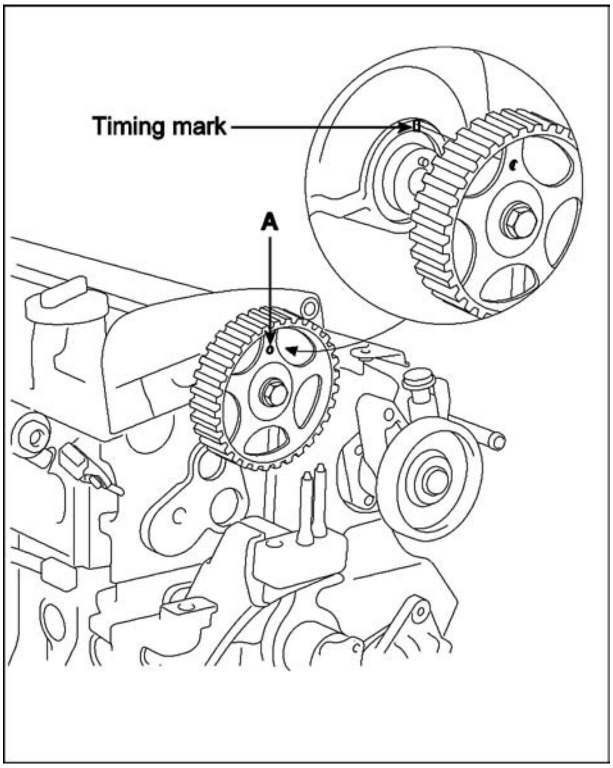
Do not bend or twist the timing belt.
Take care not to contact the timing belt with oil, water, grease and steam.

Description	Specification
1. Back side rubber is hardened	Glossy back side. Due to non-elasticity and hardening, when pressing it with the tip of a finger, there is no sign of it.  L4GC132A
2. Back side rubber is cracked	 L4GC133A
3. Canvas is cracked or detached	 L4GC134A  L4GC135A  L4GC136A
4. Tooth is excessively worn out (initial step)	Tooth loaded from canvas is worn (elastic canvas fiber rubber is worn, color is faded in white, canvas structure is deformed)  L4GC137A
5. Tooth is excessively worn out (final step)	Tooth loaded from canvas is Worn and rubber is worn off (tooth width is narrowed)  L4GC138A
6. Tooth bottom is cracked	 L4GC139A
7. Tooth is missing	 L4GC140A
8. The side of belt is severely worn out	 L4GC141A
9. The side of belt is cracked	**NOTE: In case of normal belt, it is cut precisely as if cut with a sharp cutter**  L4GC142A

Assembly



1. Install the crankshaft sprocket taking care of installation direction as shown in the illustration.



2. Install the camshaft sprocket and tighten the bolt to the specified torque.

Camshaft sprocket bolt	10 ~ 12kg·m

3. Install the idler and tighten the bolt to the specified torque.

Idler fixing bolt	4.3 ~ 5.5kg·m

4. With no.1 cylinder piston to the dead point of compression stroke, align the timing mark on the camshaft sprocket and timing mark on the crankshaft sprocket.

1) After installing the tensioner, spring and spacer and tightening the bolt temporarily, tighten the long hole shaft washer of tensioner and bolt.

2) Install the spring bottom end to the front case as shown in the illustration.

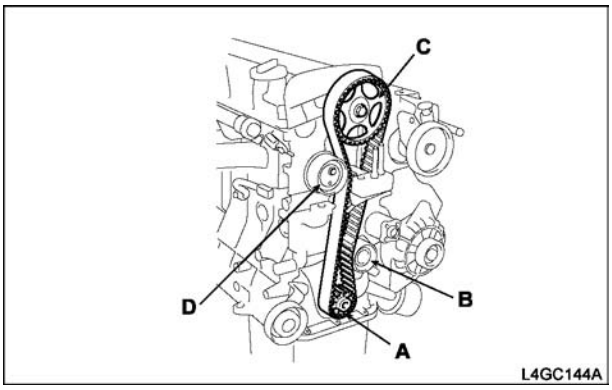
3) Install the flange and crankshaft sprocket taking care of installation direction and then tighten the washer and bolt temporarily.

4) When aligning the timing marks, after turning the cam-shaft sprocket to place the red timing mark on the cam cap in the middle of the knock pin 4.5 bore, align this timing mark with the timing mark on the front case by rotating the shaft sprocket.

5) Install the belt with the timing aligned as shown in the illustration. (When installing, start from the belt tension side and then install the belt by pressing the tensioner.

⚠ CAUTION

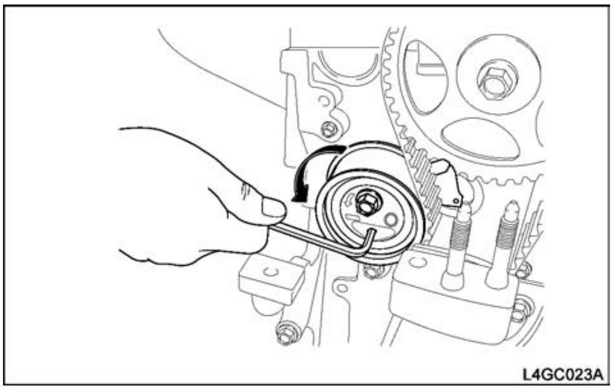
When no.1 piston is at TDC, if the camshaft sprocket mark is not aligned with head mark, interference between piston and valve occurs. So take care of timing aligning.



6) Install the timing belt not to loosen in the following order.

Crankshaft sprocket (A) → Idler pulley (B) → Camshaft sprocket (C) → Timing belt tensioner (D).

(After installing timing belt, auto tensioner may be installed)



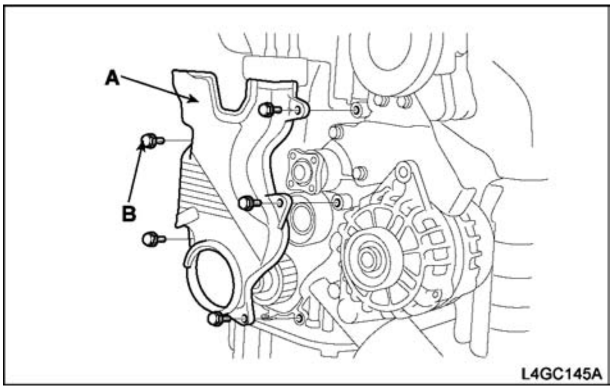
7) Be sure that timing mark on each sprocket is placed on the proper position.

8) Remove the tensioner arm fixing pin.

9) Insert a hexagonal wrench to the adjuster groove as below, rotate it counterclockwise to place the arm indicator in the middle of base groove.

⚠ CAUTION

Do not rotate the wrench clockwise, or the auto tensioner is not normally functioned.L4GC144A



10) With the arm indicator fixed not to move, tighten the tensioner fixing bolt.

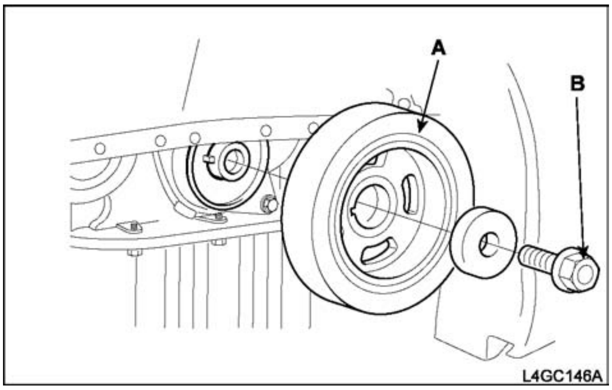
Tightening torque	2.3 ~ 2.9kgf·m

11) Rotate the crankshaft to 2 turns clockwise and then be sure that the auto tensioner arm indicator is placed in the middle of base groove.

12) If the arm indicator is out of the middle of groove, loosen the bolt and repeat the above procedure.

13) Install the timing belt lower cover.

Tightening torque	0.8 ~ 1.0kgf·m



14) Install the crankshaft pulley (A) together with the flange, tighten the bolt (B).
When installing, align the crankshaft key with the pulley groove.

Crankshaft pulley bolt

Tightening torque	16.0 ~ 17.0kgf·m

15) Install the timing belt upper cover.

Tightening torque	0.8 ~ 1.0kgf·m

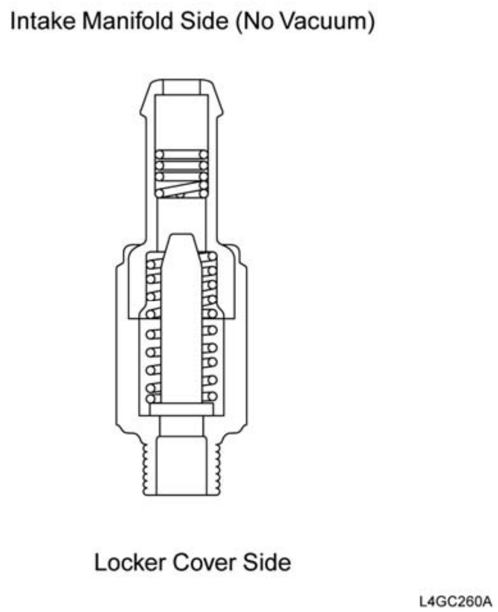
16) Install the water pump pulley.

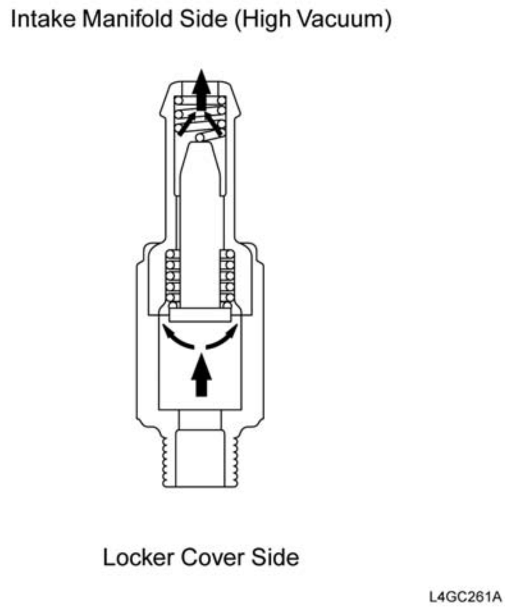
17) Install the alternator driving belt.

18) Tighten the water pump pulley fixing bolt.

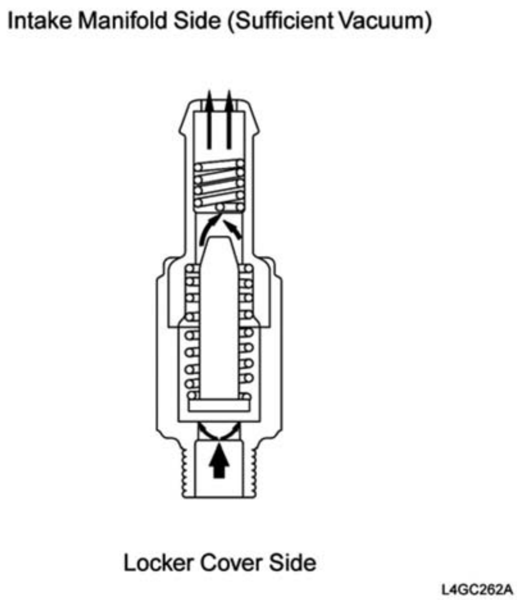
PCV Valve

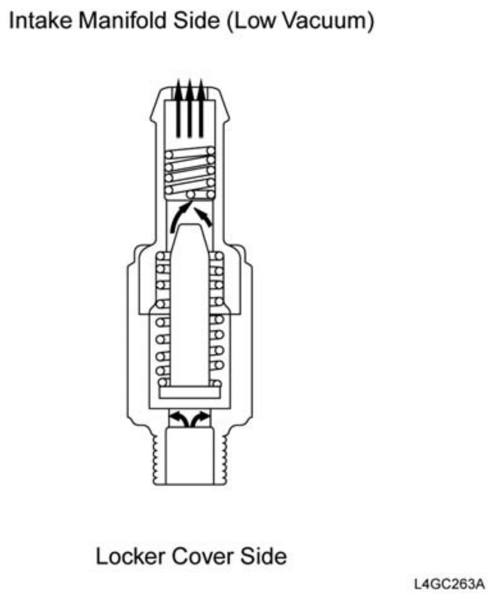
Outline and Operation Principle





Engine condition	No operating	Engine condition	At idle or deceleration
PCV valve	No operating	PCV valve	Full operating
Vacuum path	Clogged	Vacuum path	Small

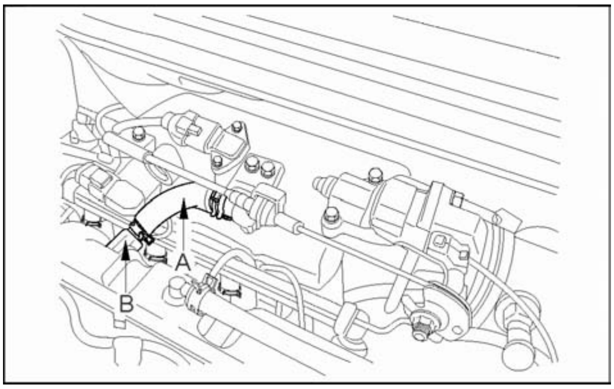




Engine condition	Proper operating	Engine condition	High speed and overload
PCV valve	Proper operating	PCV valve	Light operating
Vacuum path	Big	Vacuum path	Very big

Service Procedure

REMOVAL

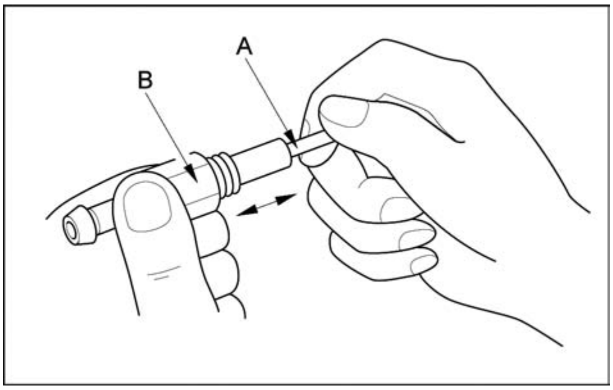


1. After disconnecting the vacuum hose (A), remove the PCV valve (B).

INSTALLATION

Install the PCV valve and connect the vacuum hose.

Tightening torque	0.8 ~ 1.2kgf·m



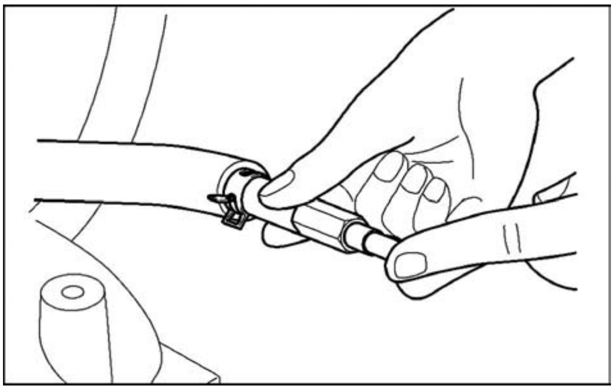
INSPECTION

1. Remove the PCV valve.

2. Check the plunger for movement by inserting a thin stick (A) toward the valve (B) nut.

3. If the plunger is not moved, it means that PCV valve is clogging, so, clean or replace PCV valve.

TROUBLESHOOTING



1. Disconnect the vacuum hose from the PCV valve. Disconnect the PCV valve from the locker cover and reconnect the vacuum hose.

2. With the engine at idle, Check the intake manifold for vacuum when clogging the opened end of PCV valve.

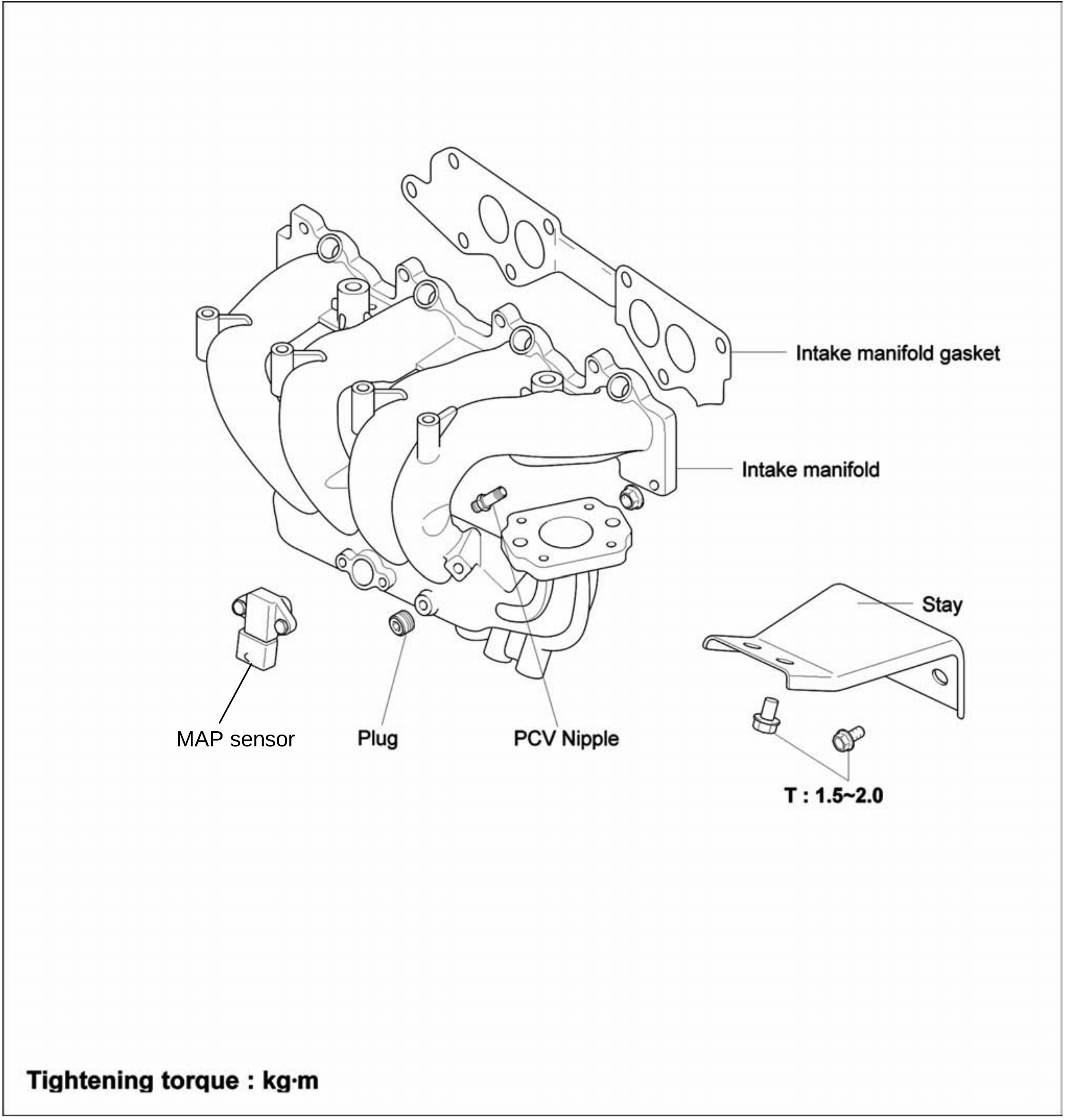
NOTE: The plunger in PCV valve will move back and forth.

3. If vacuum is not detected, clean or replace PCV valve and vacuum hose.

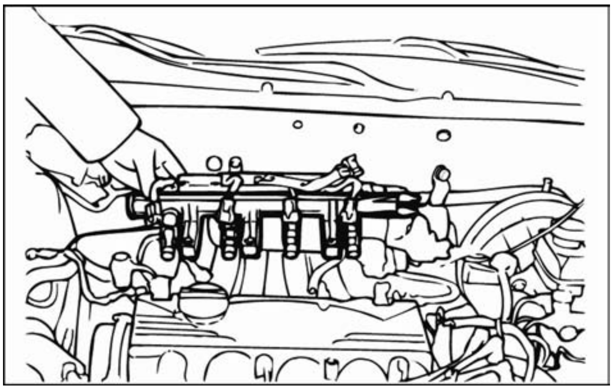
Intake and Exhaust System

Intake Manifold

Components



REMOVAL



1. Disconnect the map sensor and the connector.

2. Remove the P.C.V valve hose.

3. Disconnect the fuel injector connector and the wiring harness.

4. Remove the delivery pipe with the fuel injector attached.

⚠ CAUTION

When removing the delivery pipe, take care not to drop the injector.

5. Remove the intake manifold stay.

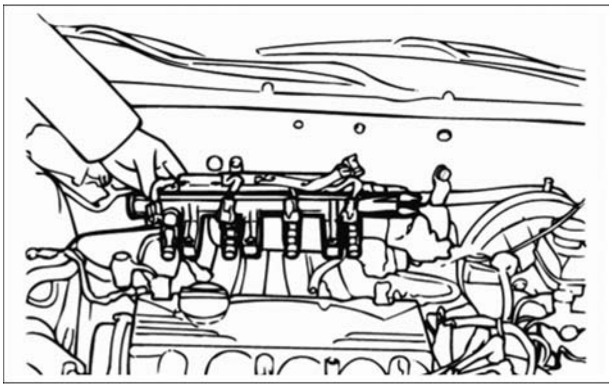
6. Remove the intake manifold and gasket.

INSPECTION

1. Intake manifold
Check each component for damage and crack.

2. Air hose
Check each component for damage and crack.

INSTALLATION



1. After replacing the intake manifold gasket, install it to the cylinder head and then to the intake manifold.

2. Install the delivery pipe and injector assembly to the intake manifold.

⚠ CAUTION

Check that the injector is interfered with the injector hole in the intake manifold.

3. Install the fuel injector connector and wiring harness.

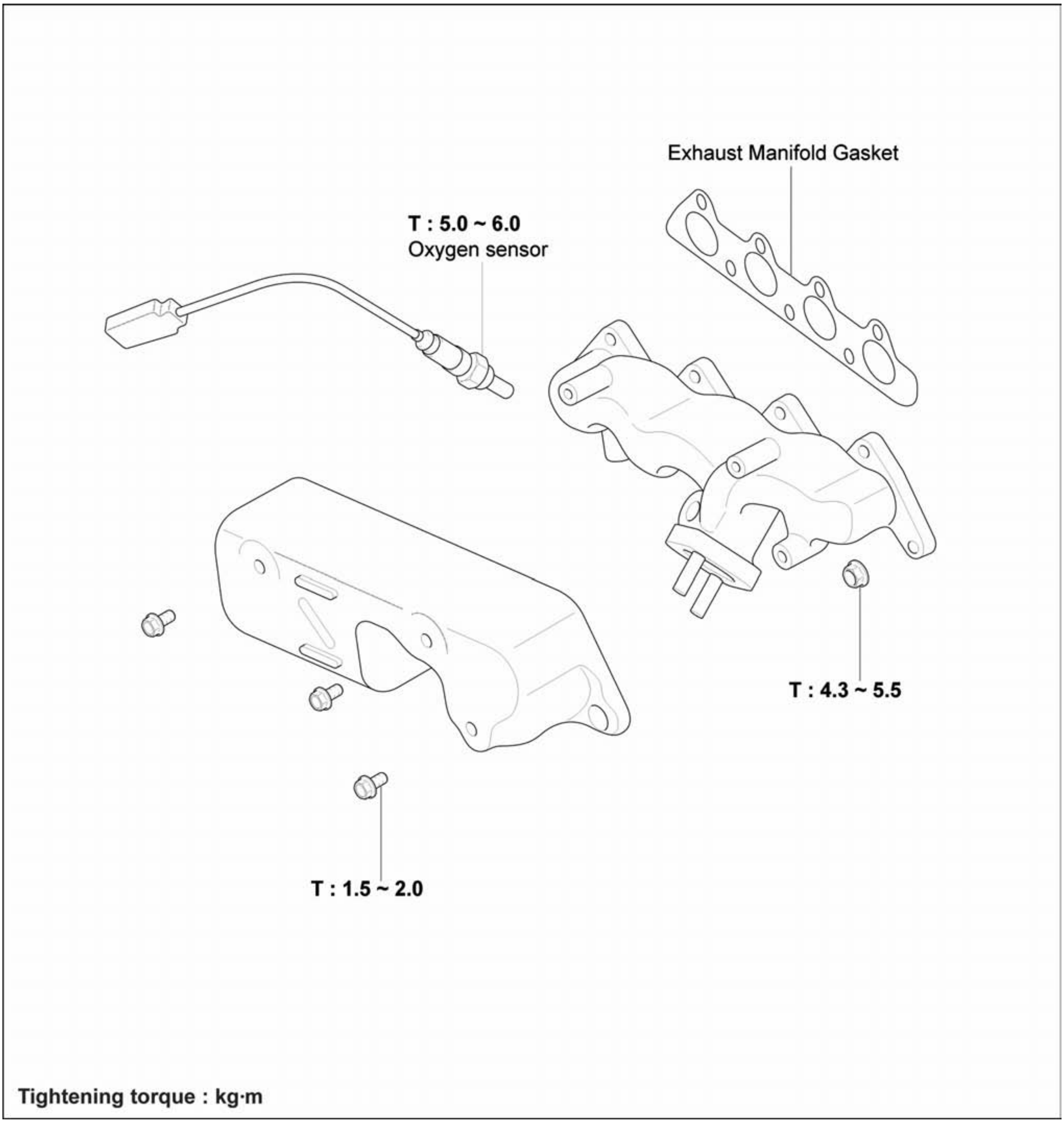
4. Connect the high-pressure fuel hose.

5. Connect the P.C.V valve hose.

6. Check connectors for connection.

Exhaust Manifold

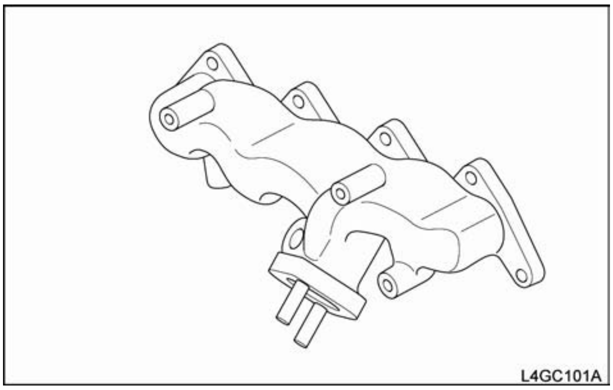
COMPONENTS



⚠ CAUTION

Do not tighten parts excessively, observe the specified torque.

REMOVAL



1. Remove the heat protector.

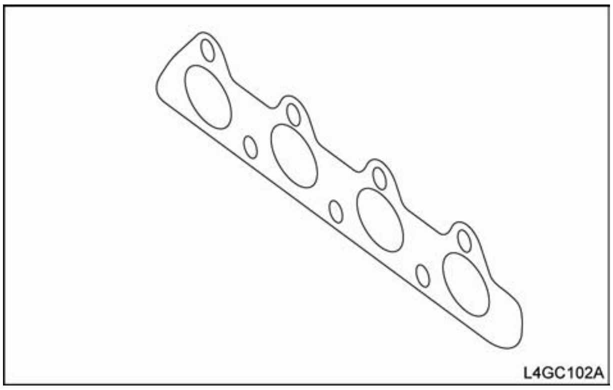
2. Detach the exhaust manifold from the cylinder head.

INSPECTION

1. Check the exhaust manifold for damage and crack.

2. Exhaust manifold gasket
Check the gasket for tear or damage.

INSTALLATION



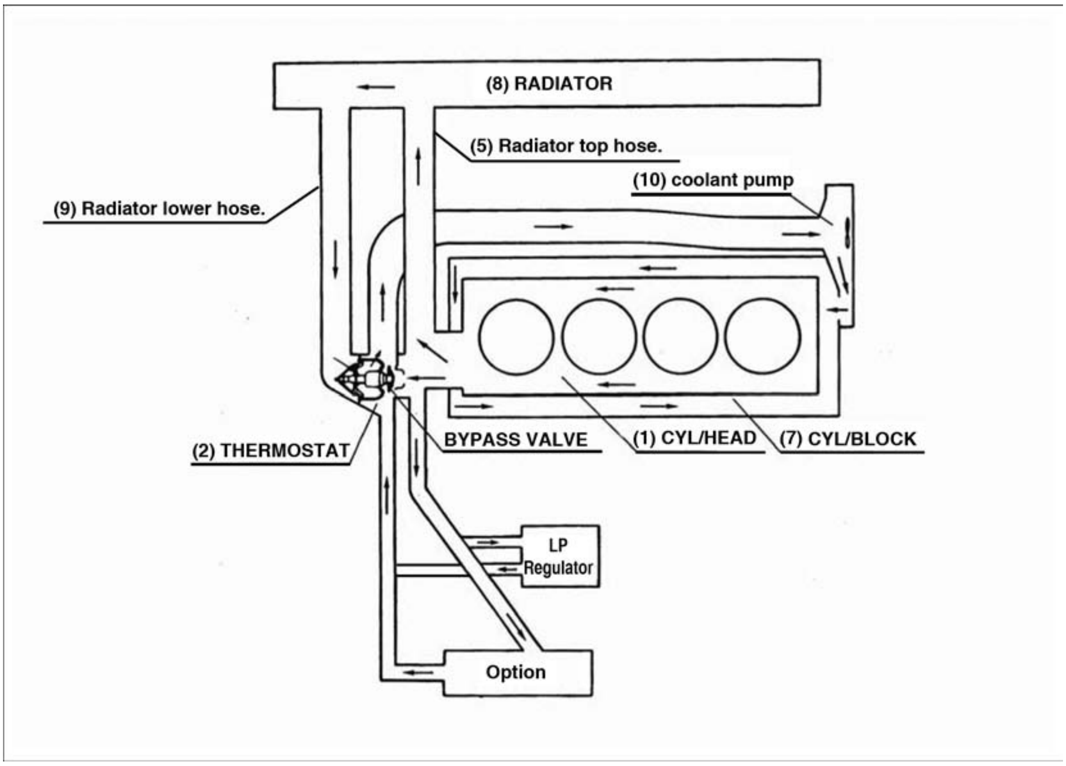
1. Installation is the reverse order of removal.

⚠ CAUTION

Do not reuse the exhaust manifold nut.

Cooling System

General Description



Cooling System Schematic

(1) Cylinder head. (2) Thermostat. (3) Recovery tank. (5) Radiator top hose. (6) Radiator pressure cap.
(7) Cylinder walls. (8) Radiator. (9) Radiator lower hose. (10) Water pump.

Water pump (10) is installed on the front of the cylinder block. The water pump is driven by a single V belt from the crankshaft pulley. The inlet opening of the water pump is connected to the radiator lower hose (9). The outlet flow from the water pump goes through passages inside the cylinder block.
The coolant from the water pump through the cylinder block passages has primary coolant flow to and around the seats for the exhaust valves. This method gives the coolant with the coolest temperature flow to the hottest area during engine operation.
Cylinder walls (7) are cooled by the coolant flow through the block. After the coolant goes through the cylinder block it flows through cylinder head (1) to the thermostat housing, where the bypass type thermostat (2) is installed. The thermostat controls the opening to radiator (8) to control the temperature in the cooling system.
If the coolant is cold (cool), the thermostat will be closed. The coolant circulates (makes a complete circuit) from the water pump and through the cylinder block until the temperature of the coolant is warm enough to make the thermostat open. When thermostat (2) is open the coolant will go through radiator top hose (5) and into the top tank of radiator (8). Coolant then goes through the cores of the radiator. The air from the fan will make the coolant cool as the coolant flows to the bottom of the radiator and out hose (9) where the coolant returns to water pump (10).
The radiator is equipped with a shroud to increase the efficiency of the fan and cause the air to be pushed through the radiator and away from the lift truck.
If the coolant is hot and the cooling system pressure is too high, some coolant flows to the top of radiator (8) through the tube to recovery tank (3). The cooling system pressure is controlled by cap (6). When the cooling system pressure goes above its rated pressure, a valve opens in pressure cap (6) which releases the cooling system pressure to the atmosphere. After the engine is at normal temperature for operation, a development of vacuum is present in the cooling system. Pressure cap (6) permits air in the radiator to remove the vacuum at the same time coolant from recovery tank (3) is pulled back into the radiator.

Testing and Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running:

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (the sudden making of low pressure bubbles in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

The cause for an engine getting too hot is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before testing with testing equipment.

Cooling System Visual Inspection

⚠ WARNING

Do not loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the filler cap (on a radiator with a pressure cap, turn it to the first stop) to let pressure out of the cooling system. Then remove filler or pressure cap.

2. Check coolant level in the cooling system.

3. Look for leaks in the system.

4. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.

5. Inspect the drive belts for the fan.

6. Check for damage to the fan blades.

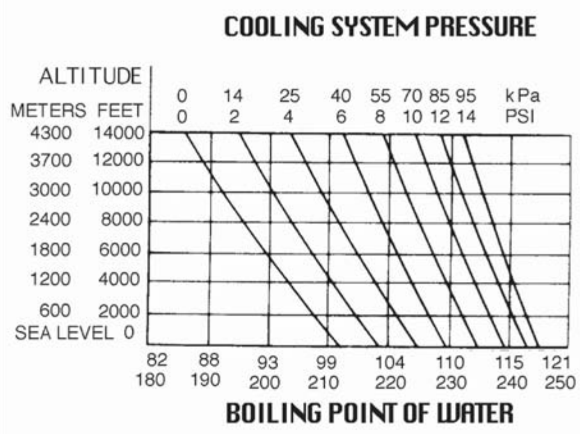
7. Look for air or combustion gas in the cooling system.

8. Inspect the filler cap and the surface that seals the cap. This surface must be clean.

9. Look for a large amount of dirt in the radiator core and on the engine.

10. Check for loose or missing fan shrouds that cause poor flow of cooling air.

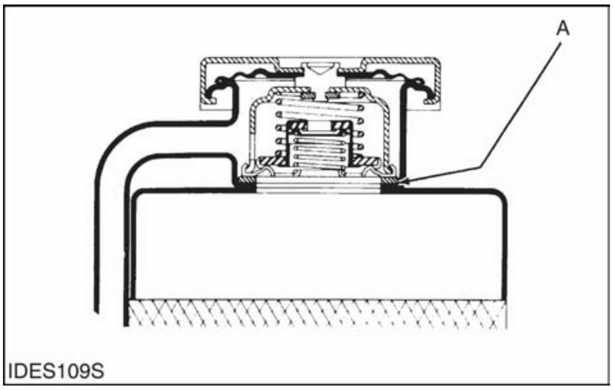
Cooling System Tests



IDES108S

Remember that temperature and pressure work together. When making a diagnosis of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.

Pressure Cap Test



Pressure Cap Diagram
(A) Sealing surface of cap and radiator.

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or the sealing surface. Any foreign material or deposits on the cap, seal or seal or sealing surface must be removed.

To check the pressure cap opening pressure, do the following procedure.

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Put the pressure cap on the Cooling System Pressurizing Pump Tool.

3. Look at the gauge for the pressure that makes the pressure cap open. It must be as follows:
A403658………76 to 100 kPa (11 to 14.5 psi)

4. If the pressure cap is bad, install a new pressure cap.

Cooling System Leak Check

To test the cooling system for leaks, use the following procedure:

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Make sure the radiator is full (hot) or nearly full (cold) of coolant.

3. Attach the Cooling System Pressurizing Pump Tool to the radiator filler neck.

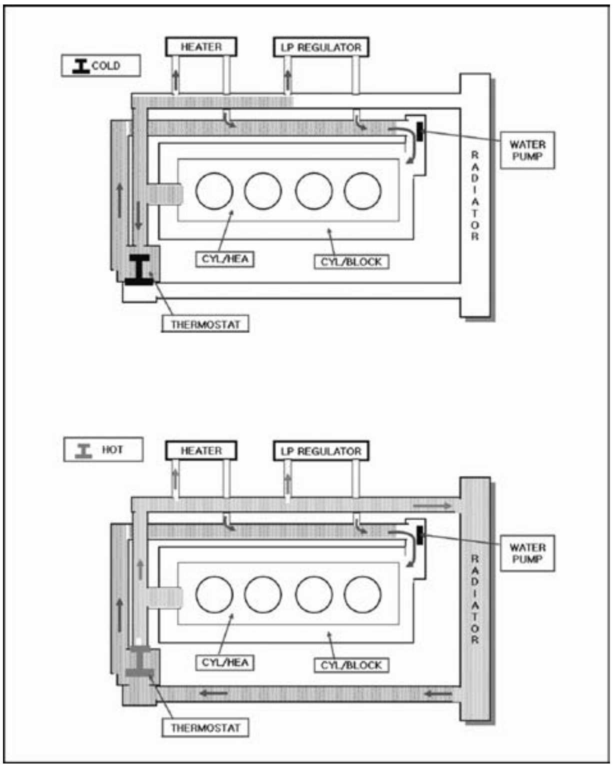
4. Pump the pressure to 20 kPa (3 psi) more than the rated pressure of the cap.

5. Check the radiator for outside leakage.

6. Check all connections and hoses of the cooling system for outside leakage.

7. If there is no outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system do not have leakage. If the reading on the gauge goes down and there is no outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary

Thermostat



The thermostat is the wax pellet type. A jiggle valve (which improves air bleeding during water supply) is provided on the flange part. When the thermostat is closed, the circulation of coolant is stopped, thereby making warm-up faster.

Operation

When the temperature of the coolant is low, the valve is closed by the spring, with the result that the coolant circulates within the engine, without passing through the radiator.
When the temperature of the coolant rises and reaches a certain specified temperature, the valve opens and the coolant also circulates through the radiator.

When the temperature increases further and reaches a certain specified temperature, the valve opens fully, allowing even more coolant to circulate through the radiator.

Thus, in this way the degree of valve opening is varied according to the temperature of the coolant, and the temperature of the coolant is adjusted by varying the amount of coolant caused to circulate through the radiator.

Thermostat Test

To test the thermostat opening temperature, use the following procedure:

⚠ WARNING

The pan, water and thermostat will be very hot and can cause burns. Do not touch the pan, water or thermostat. Handle the components with an insulated device for protection.

1. Remove the thermostat from the engine.

2. Hang the thermostat in a pan of water. Put a thermometer in the water. Put the thermostat completely under water. Do not let the thermostat make contact with the pan.

3. Put heat to the pan of water. Make the water in the pan move around. This keeps all of the water at the same temperature.

4. The thermostat must start to open when the temperature is 82°C (180°F). The thermostat must be fully open at 96°C (205°F).

Cooling System Heat Problems

To check if there is a good reason for heat problems do the checks that follow:

1. The indications of a heat problem are as follows:

a. High coolant temperature indicator light is on or needle of coolant temperature gauge is in red range.

b. Coolant boils out (comes out because of too much heat) of the cooling system during operations.

c. Coolant boils out on the floor when the engine is stopped.

d. Coolant must be added at the end of each shift but Steps b and c are not present.

2. If indication in Step 1 a is only present. It is possible the problem is only a damaged gauge, light or sender. Make a replacement of the defective part.

3. If indication in Step 1b is present, do the procedure that follows:

a. Run the engine at medium idle (1200 rpm) for three minutes after high idle operation. This cools off the hottest parts of the engine before it is stopped.

b. Install a coolant recovery system on the truck, if not already equipped.

4. If indications in Step 1b, 1c or 1d are present, but Step 1a is not and the high temperature indicator light does work, the problem can be a damaged radiator cap seal or there can be a leak in the cooling system. Complete the procedure that follows:

a. Do the Pressure Cap Test, Cooling System Leak Check, Thermostat Test and Belt Adjustment in the Testing And Adjusting.

b. Clean the radiator with hot water (steam clean) at low pressure and use detergent or air according to the different types of debris that caused the radiator to be dirty (plugged).

c. Check the engine high idle setting.

NOTE: Another condition that can cause heat problems is the ignition timing. Retarded (late) timing causes the engine to send more heat to the cooling system. Advanced (early) timing causes the engine to send less heat to the cooling system.

Cooling System Recommendation

Coolant Information

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ WARNING

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

To prevent damage to your engine, never add coolant to an overheated engine. Allow the engine to cool first.
If the lift truck is to be stored in, or shipped to, an area with freezing temperatures, the cooling system must be protected to the lowest expected outside (ambient) temperature.

The engine cooling system is protected with a commercially available automotive antifreeze, when shipped from the factory.

Check the specific gravity of the coolant solution frequently in cold weather to ensure adequate protection.

Clean the cooling system if it is contaminated, if the engine overheats or if foaming is observed in the radiator.

Old coolant should be drained, system cleaned and new coolant added as recommended with the commercially available automotive antifreeze.

Filling at over 20 liters per minute can cause air pockets in the cooling system.

After draining and refilling the cooling system, operate the engine with the radiator cap removed until the coolant reaches normal operating

temperature and the coolant level stabilizes. Add coolant as necessary to fill the system to the proper level.

Operate with a thermostat in the cooling system all year-round. Cooling system problems can arise without a thermostat.

Coolant Water
Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (ppm)
Chlorides (CI)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Using water that meets the minimum acceptable water requirement may not prevent drop-out of these chemical compounds totally, but should minimize the rate to acceptable levels.

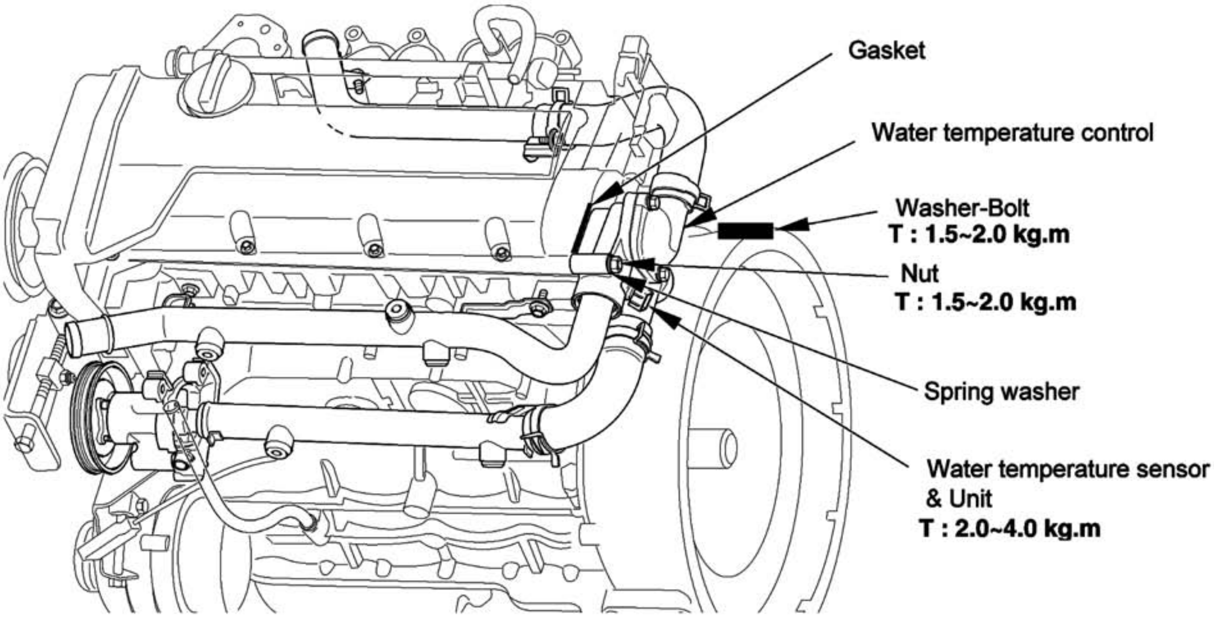
Antifreeze
DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Make proper antifreeze additions.

Adding pure antifreeze as a makeup solution for cooling system top-up is an unacceptable practice. It increases the concentration of antifreeze in the cooling system which increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system. Add antifreeze mixed with water to the same freeze protection as your cooling system.

Coolant Pipe and Hose

COMPONENTS



Tightening torque : kg·m

INSPECTION

Check the coolant pipe and hose for crack, damage, and clogging and replace it if necessary.

INSTALLATION

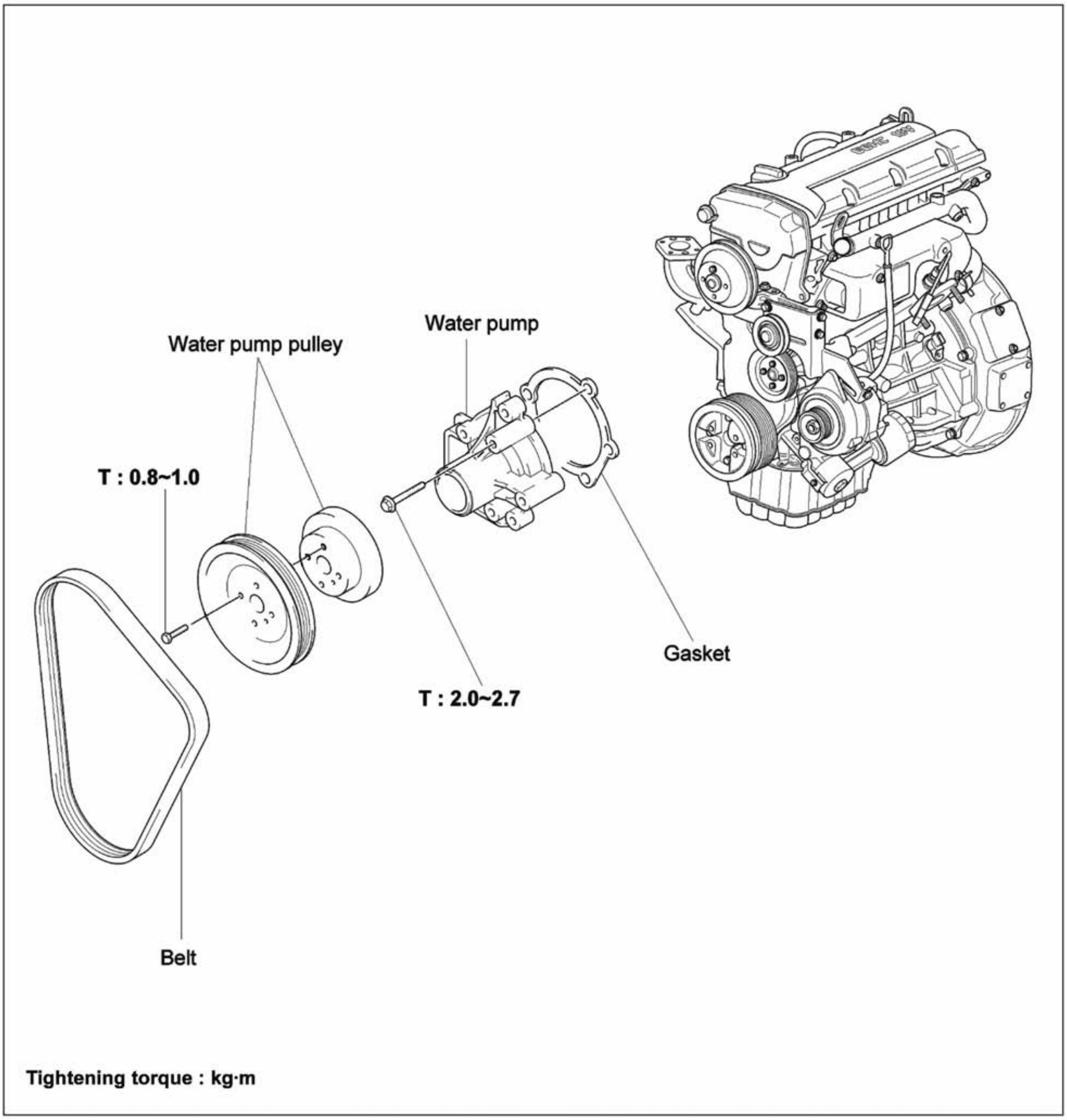
After getting water around O-ring, insert it the groove in the coolant intake pipe end and press-fit the pipe.

⚠ CAUTION

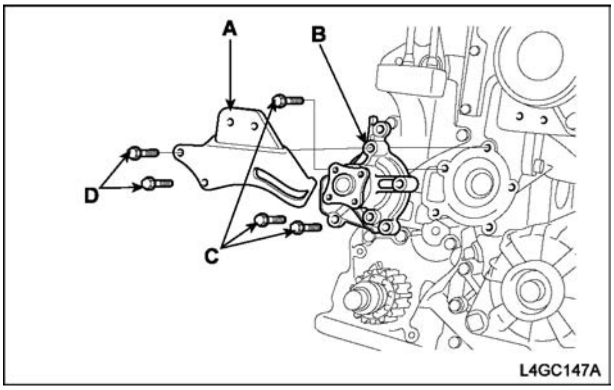
Do not apply oil or grease to the O-ring.
Take care not to dirt the coolant pipe connecting part with sand or dust.
Press-fit the coolant intake pipe completely.

Water Pump

COMPONENTS



REMOVAL



1. Drain the engine coolant.

⚠ CAUTION

System is under high pressure when the engine is hot. To avoid danger of releasing scalding engine coolant, remove the cap only when the engine is cool.

2. Remove drive belts.

3. Remove the timing belt.

4. Remove the timing belt idler.

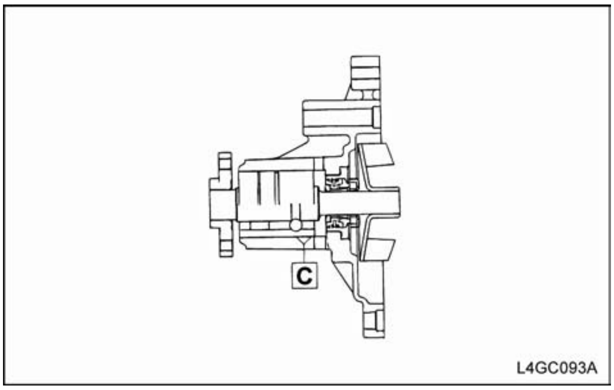
5. Remove the water pump.

1) Remove the 4 bolts and pump pulley.

2) Remove the 3 bolts (C), then remove the alternator brace (A).

3) Remove the water pump (B) and gasket.

INSPECTION

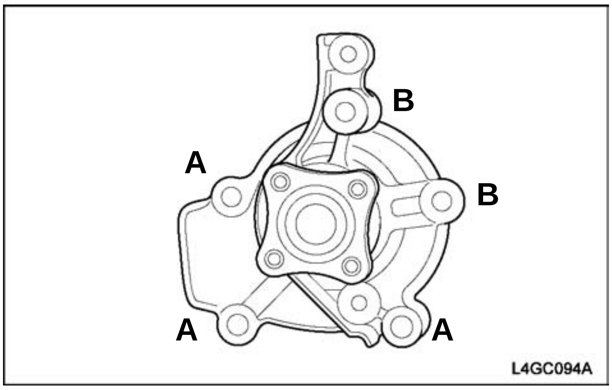


1. Check each part for crack, damage, and wear and replace the water pump if necessary.

2. Check the bearing for damage, abnormal noise and bad rotation and replace the water pump if necessary.

3. Check the seal unit from C hole for leak and replace the water pump assembly if necessary.

INSTALLATION



1. Clean the gasket surface of the water pump body and cylinder block.

2. After getting water around new O-ring, install it the groove in the coolant intake pipe front end. Do not apply oil or grease to the O-ring.

3. Install a new water pump gasket and water pump assembly. Tighten it to the specified torque.

WATERPUMP AND CYLINDER BLOCK

A	2.0 ~ 2.7 kg·m
B	2.0 ~ 2.4 kg·m

4. Install the timing belt tensioner and timing belt. Adjust the timing belt tension and install the timing belt cover.

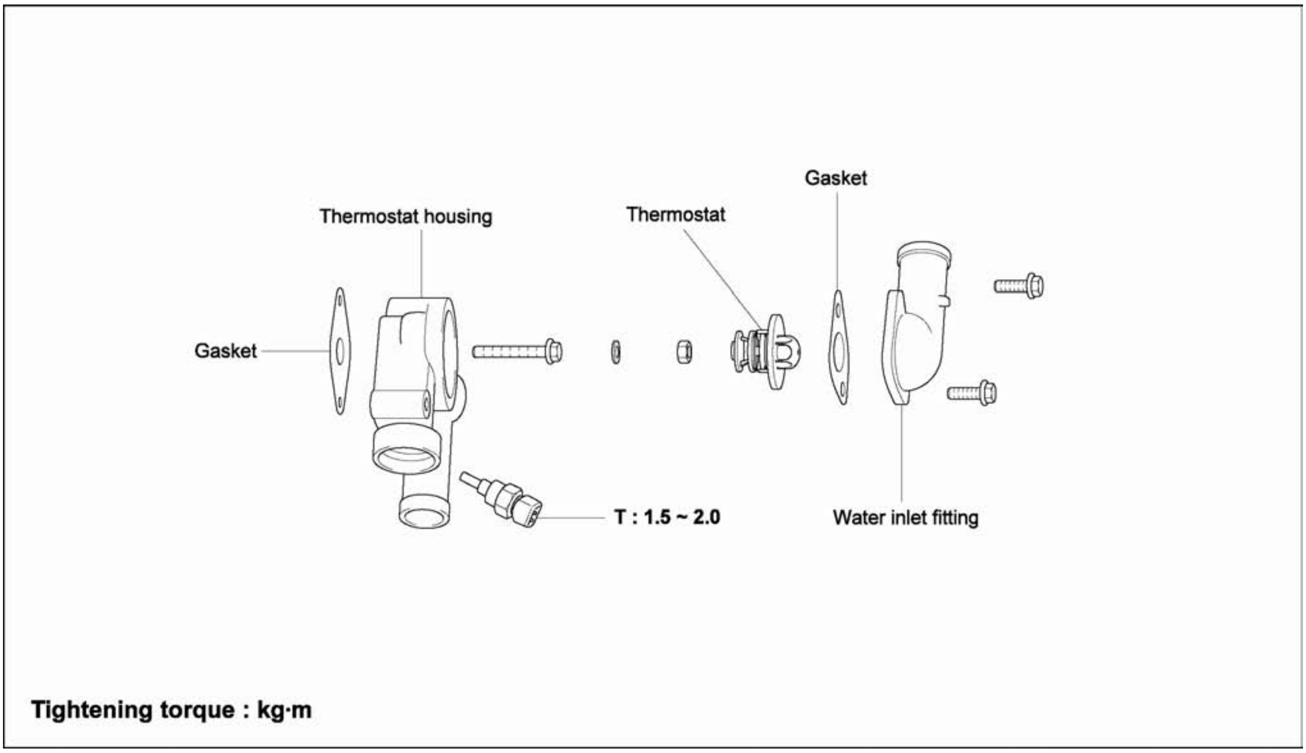
5. After installing the water pump pulley and driving belt, adjust the belt tension.

6. Add the standard coolant.

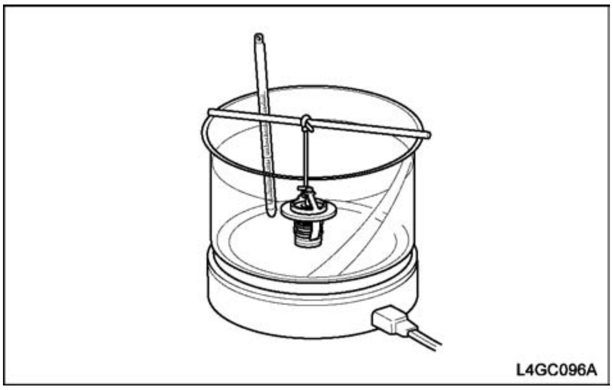
7. Run the engine and check for leak.

Thermostat

COMPONENTS



INSPECTION



1. Check the valve closed at room temperature.

2. Check for defect or damage.

3. Heat the thermostat as shown in the illustration and measure the valve open temperature and full open temperature.

Valve open temperature

Open	82°C
Full open	95°C

INSTALLATION

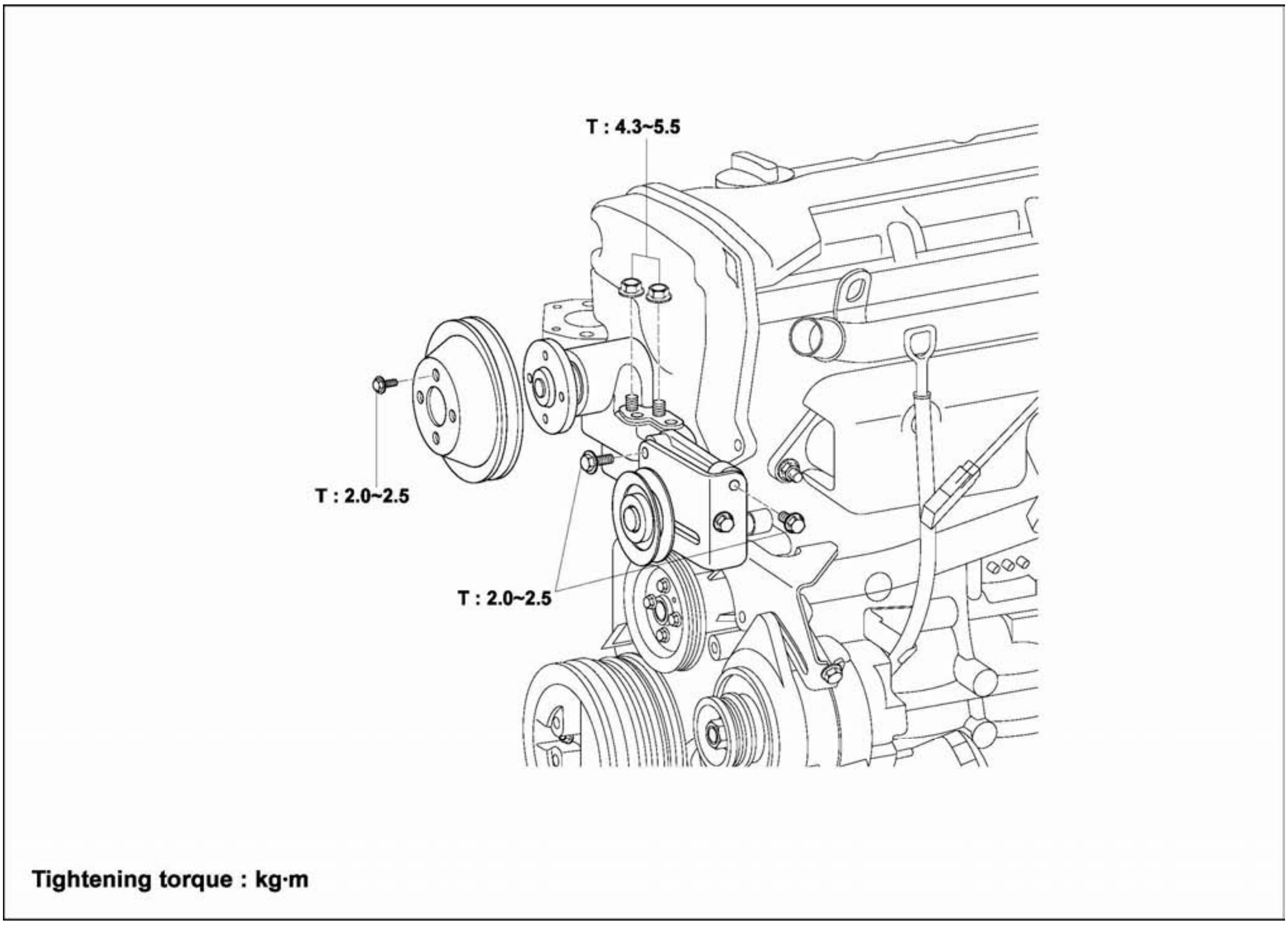
1. Check that the thermostat flange is correctly inserted to the thermostat housing socket. At this time, upward the jiggle valve and make contact to the hole.

2. Install a new gasket and water inlet fitting.

3. Add coolant.

FAN DRIVE

COMPONENTS



REMOVAL

1. Remove the fan pulley.

2. Remove the fan bracket.

INSPECTION

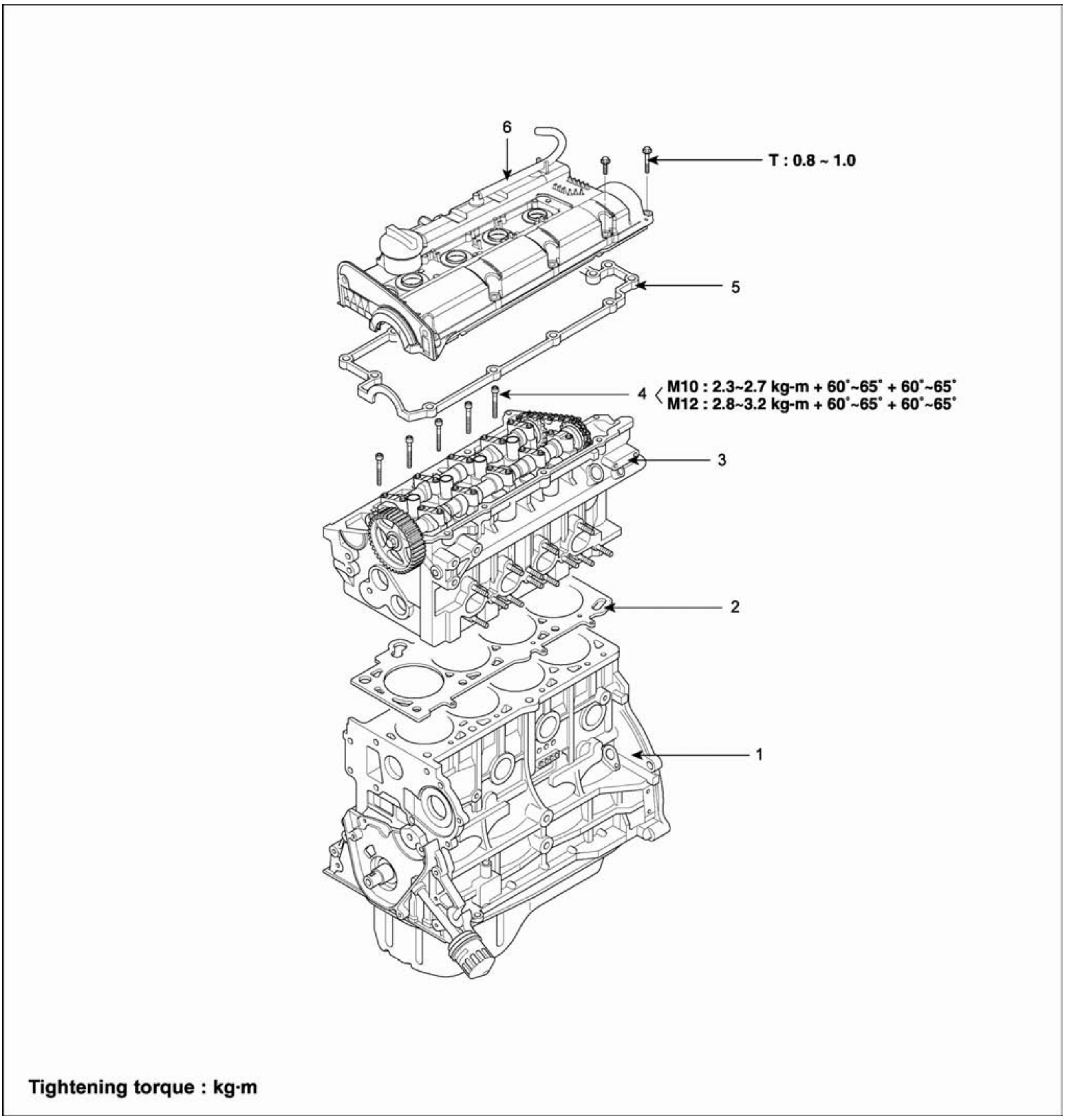
Check the bearing for damage, abnormal noise and sluggish rotation, and replace the bracket assembly if necessary.

INSTALLATION

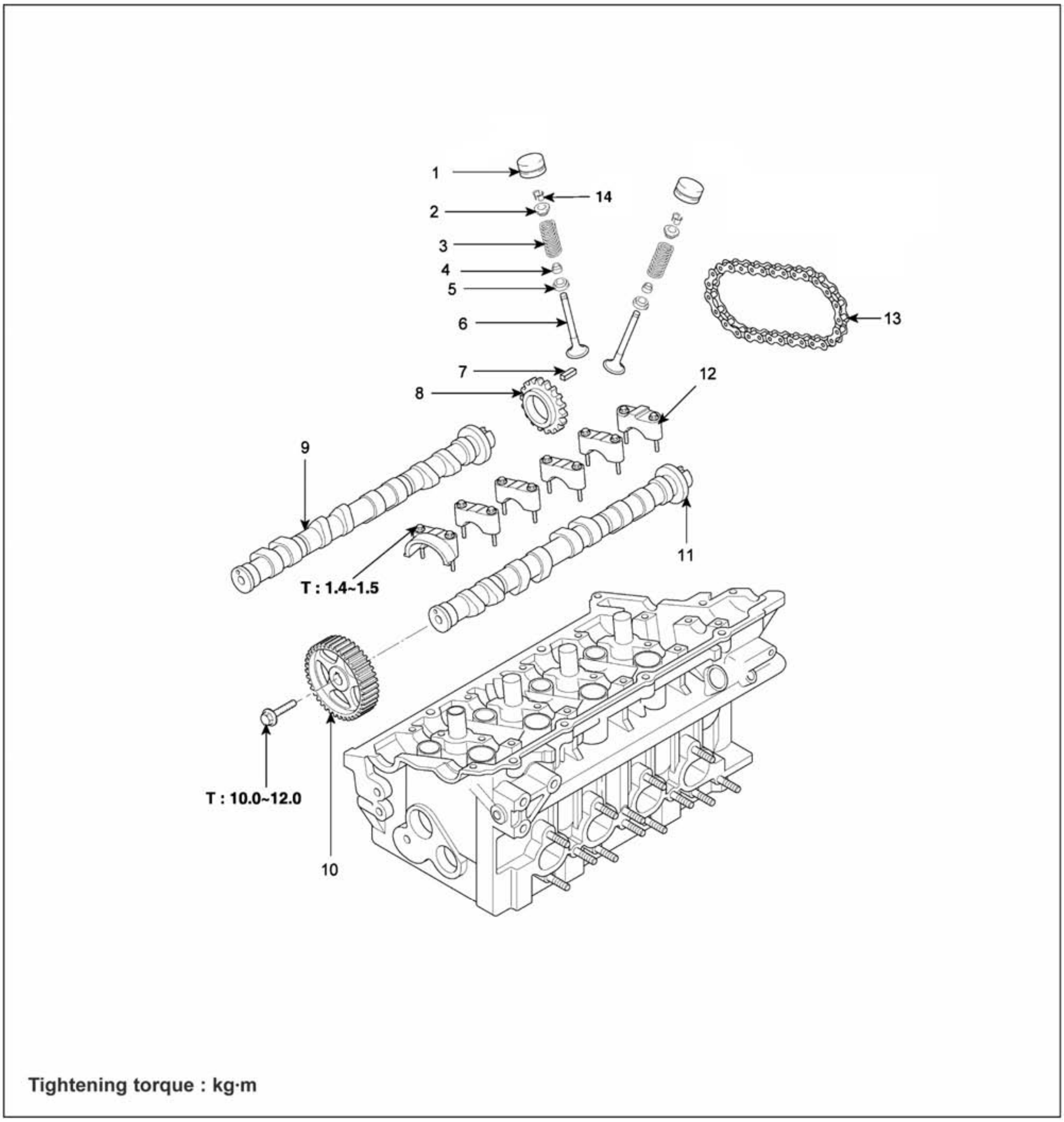
Installation is the reverse order of removal.

Cylinder Head Assembly

Components

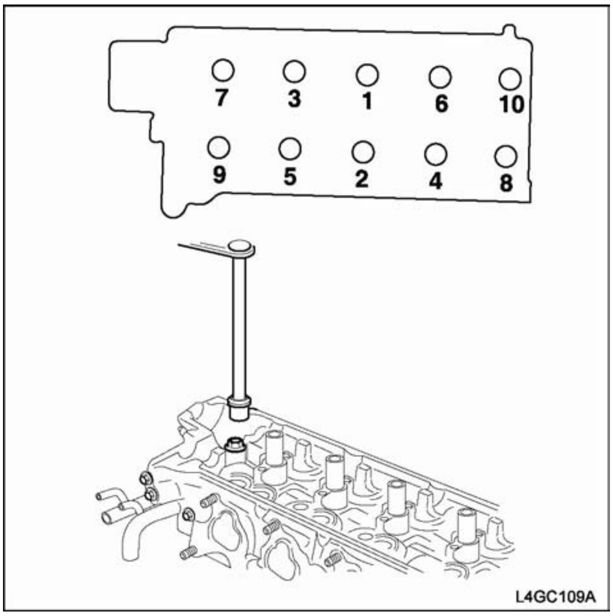


1. Cylinder block
2. Cylinder head gasket
3. Cylinder head
4. Cylinder head bolt
5. Gasket
6. Cylinder head cover



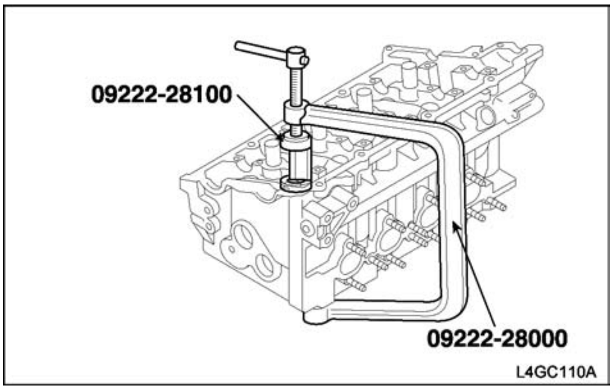
1. HLA(Hydraulic Lash Adjuster)
2. Retainer
3. Valve spring
4. Stem seal
5. Spring seat
6. Valve
7. Key
8. Chain sprocket
9. Intake camshaft
10. Camshaft sprocket
11. Exhaust camshaft
12. Camshaft bearing cap
13. Timing chain
14. Retainer lock

Disassembly



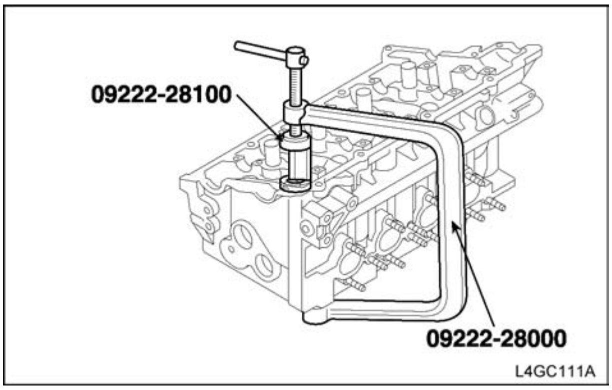
1. Using the 8mm and 10mm hexagon wrench, tighten the cylinder head bolts in order by tightening 2-3 times as shown in the illustration.

• Take care not to come the cylinder head gasket debris into the cylinder.



2. Using the special tool "valve spring compressor (09222-28000, 09222-28100)", remove the retainer lock.
And then, remove the spring retainer, valve spring, spring seat and valve.

NOTE: Arrange parts in order disassembling not to make a mistake while reassembling.

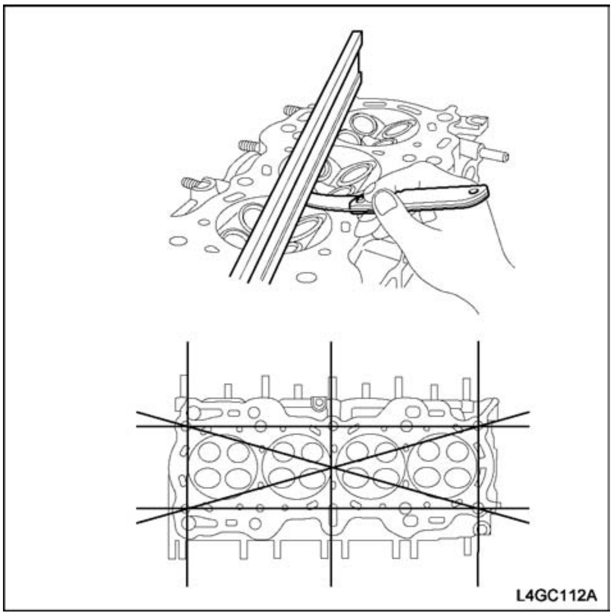


3. Remove the stem seal with pliers.

NOTE: Do not reuse the stem seal.

Inspection

Cylinder Head



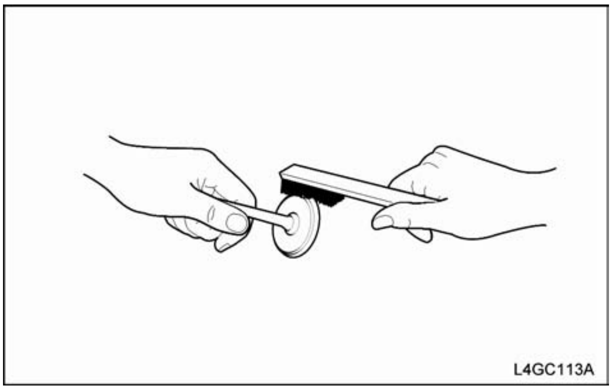
1. Check the cylinder head for crack, damage and leak.

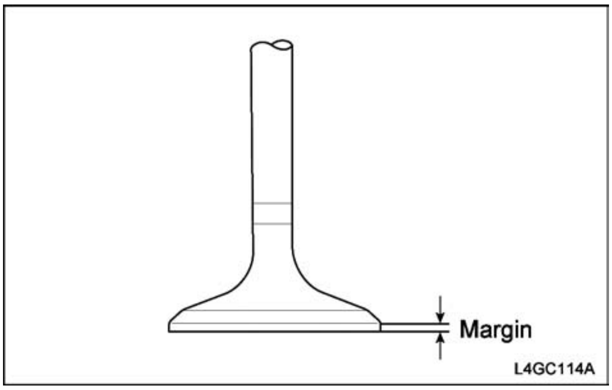
2. Clean out fur, adhesive and accumulated carbon and after cleaning the oil passage, bleed the passage with compressed air to check it for clogging.

3. Using a square, check the cylinder head gasket for flatness from shown in the illustration. If any flatness is out of the limit, replace the cylinder head or slightly cut the cylinder head gasket surface.

Flatness of cylinder Head gasket surface	Standard	0.03mm or less
	Limit	0.06mm

Valve



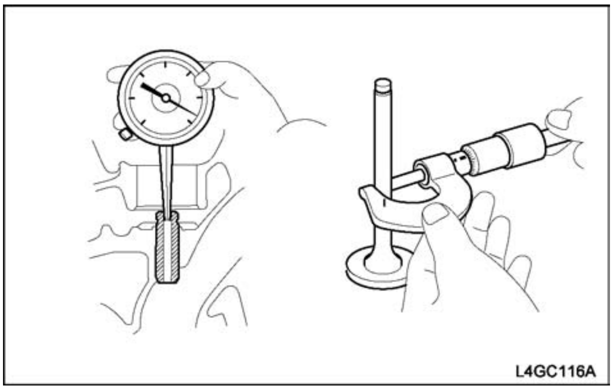


1. Clean the valve with a wire brush.

2. Check each valve for wear and damage and inspect the head and stem for torsion.
If the stem end is cave or worn, trim it.
At this time, trim it least.
Also, trim the valve surface.
If the margin is less than the limit, replace the valve.

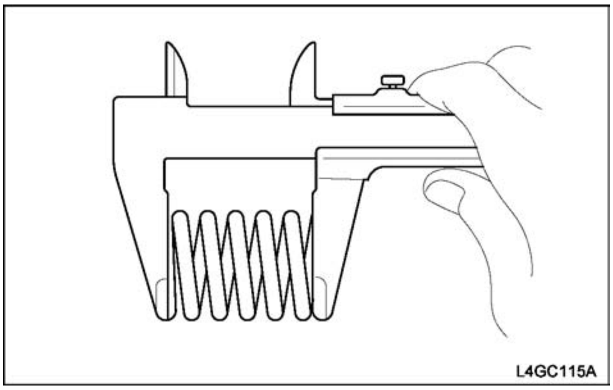
Valve margin

Standard	Intake	1.15mm
	Exhaust	1.35mm
Limit	Intake	0.8mm
	Exhaust	1.0mm



3. Measure the clearance between the valve stem and guide and if the measured value exceeds the limit, replace the valve guide and valve.

Valve stem and guide clearance



Standard	Intake	0.02 ~ 0.05mm
	Exhaust	0.035 ~ 0.065mm
Limit	Intake	0.1mm
	Exhaust	0.13mm

VALVE SPRING

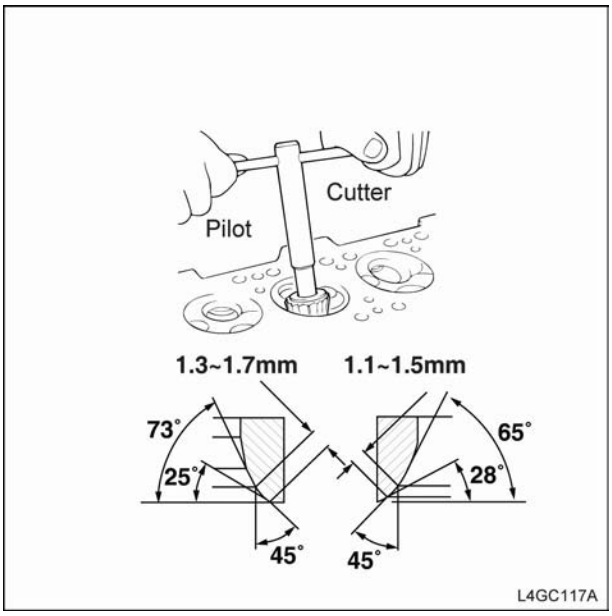
1. Measure free height of the valve spring and replace the spring if the measured value exceeds the limit.

2. Using a square, measure squareness of each spring and replace it if the measured value is out of squareness excessively.

Valve spring

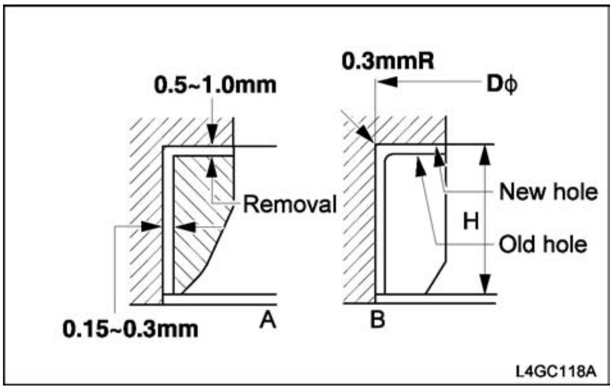
Standard	Free height	48.86mm
	Installed load	18.3kg / 39mm
	Compressed load	40.0kg / 30.5mm
	Out-of-squareness	1.5°or less
Limit	Free height	-1.0mm
	Out-of-squareness	3°

VALVE SEAT CORRECTION



Check the valve seat for overheat and inspect contact with valve surface. Correct or replace it if necessary. When correcting, check the valve guide for wear, if it is worn, replace the guide and correct the seat ring. Using a grinder or a cutter, correct the valve seat to make the seat contact width to the standard. When correcting the exhaust valve seat, must use the valve seat voce and pilot, after correcting, must apply a light coat of compound to the valve and valve seat.

VALVE SEAT RING REPLACEMENT



1. If the valve seat insert is excessively worn, cut the insert ring wall as shown in the illustration “A” using a valve seat cutter at a normal temperature.

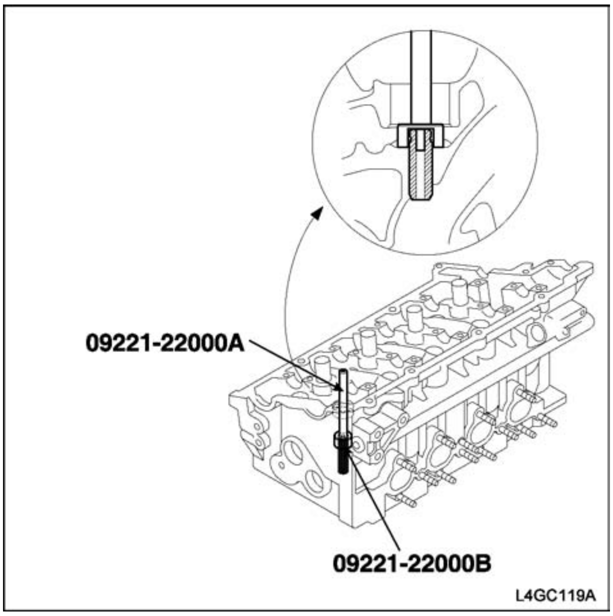
2. After removing the seat ring, Cut the seat insert bore as same size as the following table as shown in the illustration “A” using a reamer or cutter.

3. Heat the cylinder head to 250°C and press-fit the oversize seat.
At this time the oversize seat ring maintains a normal room temperature.
After installing a new valve seat, correct the valve seat surface.

Valve seat ring oversize

Item	Size(mm)	Size mark	Cylinder insert height H (mm)	Cylinder head I.D (mm)
Intake valve seat ring	0.3 OS	30	7.5 ~ 7.7	33.330 ~ 33.325
	0.6 OS	60	7.8 ~ 8.0	33.600 ~ 33.625
Exhaust valve seat ring	0.3 OS	30	7.9 ~ 8.1	28.800 ~ 28.821
	0.6 OS	60	8.2 ~ 8.4	29.100 ~ 29.121

VALVE GUIDE REPLACEMENT



Because the valve guide is press-fitted, replace the valve guide as the following procedures using a valve guide installer or proper tool.

1. Remove the valve guide pressed toward cylinder block using a push rod of valve guide installer.

2. Cut the valve guide insert bore of the cylinder head to the valve guide oversize.

3. Press-fit the valve guide using a valve guide installer or proper tool. When using a valve guide installer, Use a valve guide installer to press-fit the valve guide to the specified height.

4. When installing, start from top of valve guide cylinder head.
Be sure that the intake valve guide is not same size with the exhaust valve guide. (Intake valve guide : 46.0mm, ex-haust valve guide : 54.5mm)

5. After installing the valve guide, insert a new valve and check for perturbation.

6. When replacing the valve guide, check the valve for con-tact and correct the valve seat if necessary.

Valve guide oversize

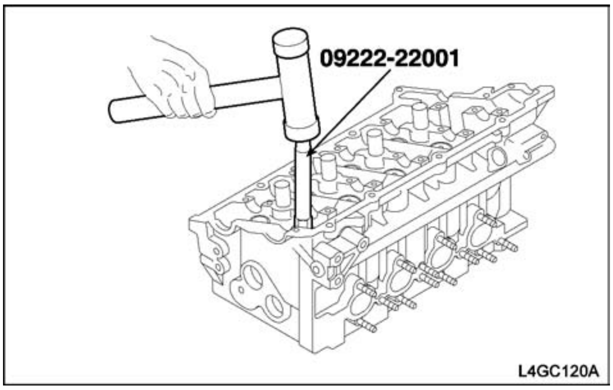
Size	Size mark	Cylinder head bore size
0.05 OS	5	11.05 ~ 11.068mm
0.25 OS	25	11.25 ~ 11.268mm
0.50 OS	50	11.50 ~ 11.518mm

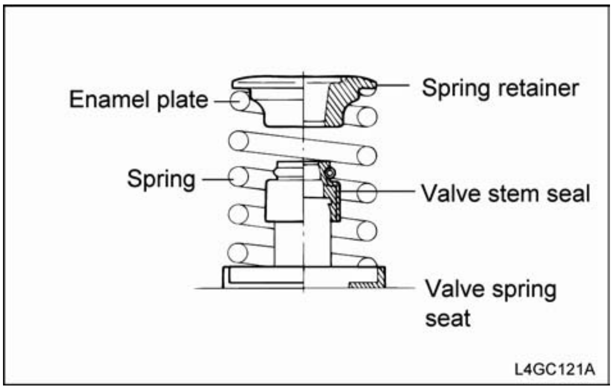
ASSEMBLY

⚠ CAUTION

Prior to assembly, clean each component.
Apply a new engine oil to the perturbation part and rotation part.
Replace a new oil seal.

VALVE

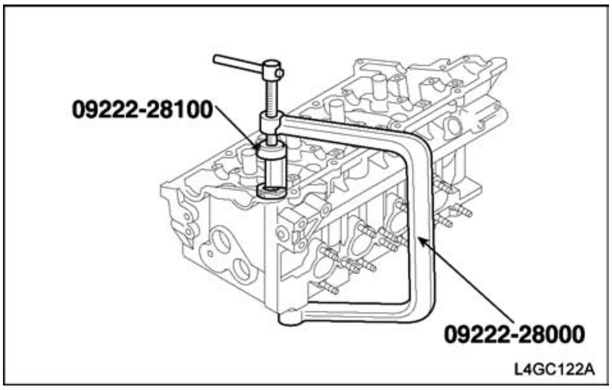




1. After installing the spring seat, insert the stem seal to the valve guide.
Install the stem seal by tapping on it with the special tool valve stem oil seal installer (09222-22001)
Wrong installation of the seal can affect oil leak from the valve guide, so use the special tool to install it to exact position and take care not to twist it. Do not reuse it.

2. After applying engine oil to each valve, insert the valve into the valve guide.

3. Install the spring and spring retainer. Face the enamel-plated side toward the valve spring retainer side.

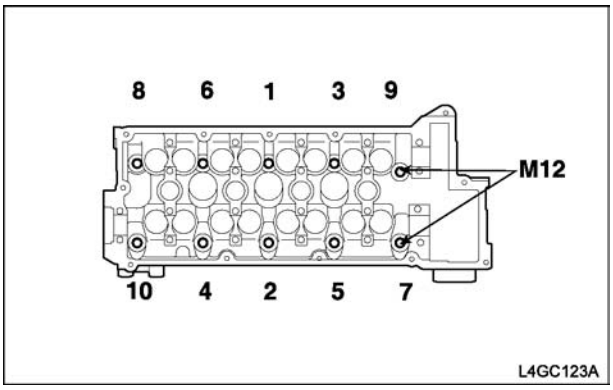


4. Taking care not to press the valve stem seal down to the retainer bottom, press-fit the spring with the special tool valve spring compressor (09222-28000, 09222-28100)and put the retainer lock in.
Remove spring compressor after pisition retainer lock exactly.

5. Hit the end of valve two or three times by rubber malet, so that valve and retainer lock is in position.

6. Assembly the HLA using by hand.

HEAD



1. Clean out all gasket surfaces of the cylinder block and cylinder head.

2. Put new cylinder head gaskets on the cylinder block with the identification marks faced upward. Do not apply seal-ant to the gasket and do not reuse the used cylinder head gasket. Take care not to make a mistake of gasket.

3. Put the cylinder head on the cylinder block.

4. Apply a slight coat of engine oil to the spiral portion of bolt.

5. Insert the washer to the bolt and insert it to the cylinder head.

6. Using the 8mm and 10mm hexagon wrench, install the cylinder head bolt as shown in the illustration.

Cylinder head bolt

M10	2.5kg·m + (60°~ 65°) + (60°~ 65°)
M12	3.0kg·m + (60°~ 65°) + (60°~ 65°)

7. Install the camshafts.

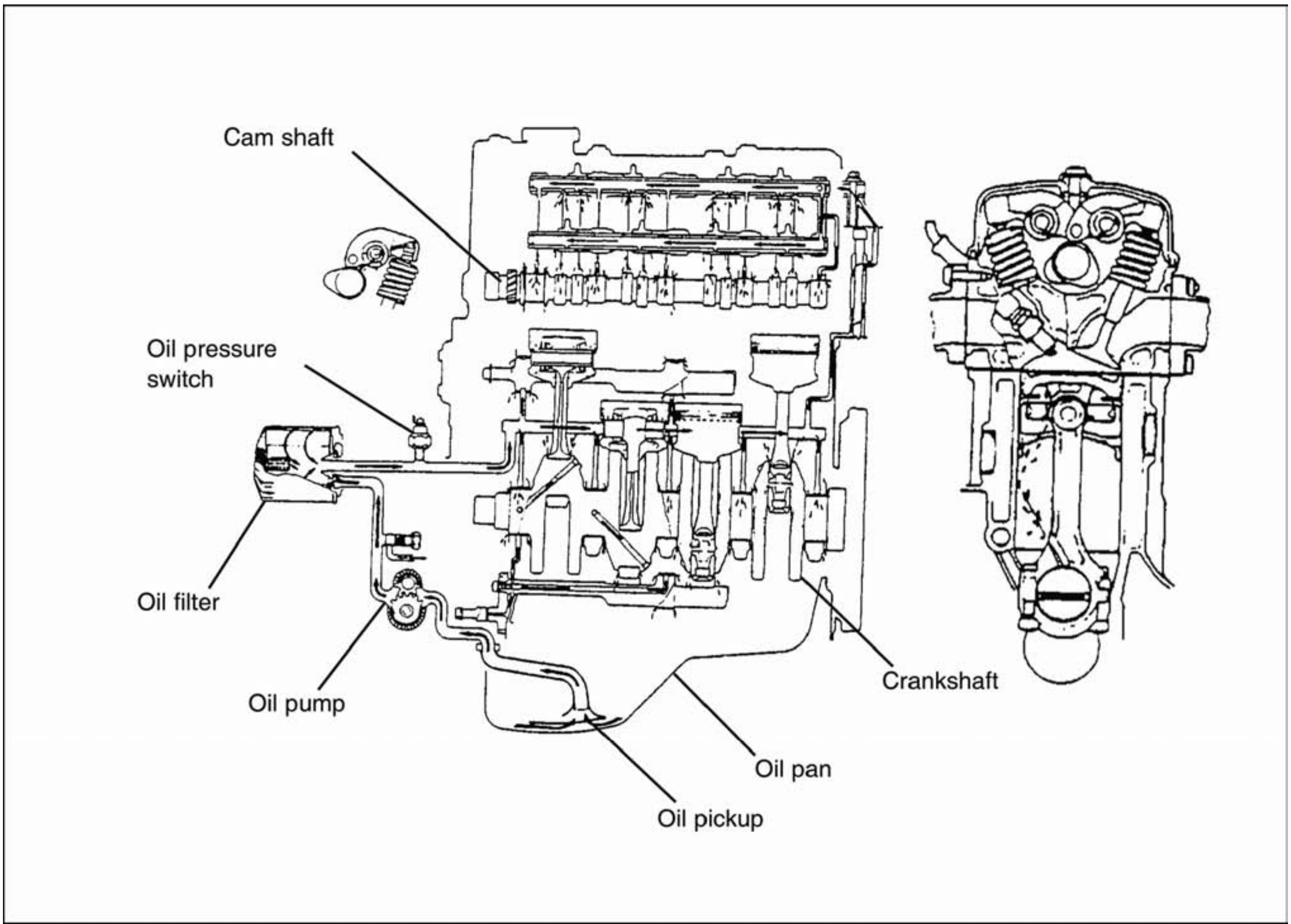
8. Install the camshafts oil seal.

9. Install the camsprocket and timing belt.

10. Install the head cover.

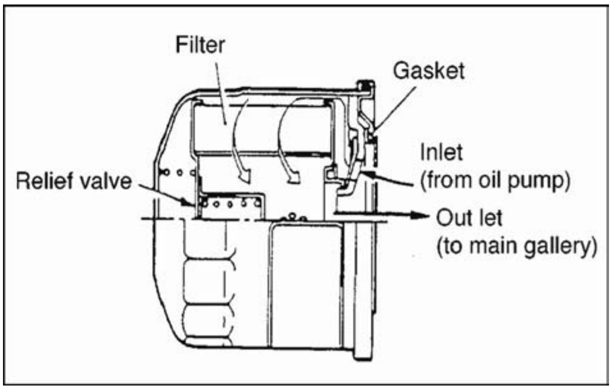
Lubrication System

General Description



Lubricating system is the full-flow filtered pressure-feed oil system and the oil reserved in the oil pan is fed with pressure to each part of engine. After the oil pressure is adjusted through the relief valve, the oil is fed to the cylinder blocks and cylinder head.
In the cylinder head the oil is forcibly fed to the camshaft journals, rocker arm pivots and further cam surfaces.

OIl Filter



Testing and Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

Engine Oil

Engine Oil Recommendation

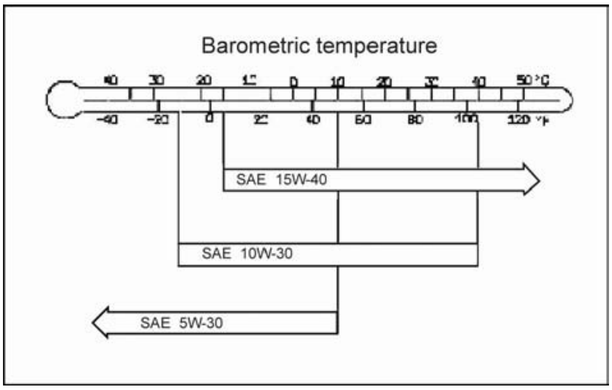
The following oil specifications provide the guidelines for the selection of commercial products : Use gasoline engine oil. Recommended API service classification is class SJ grade.

NOTICE

Failure to follow the oil recommendations can cause shortened engine life due to carbon deposits or excessive wear.

Prior to changing oil, select an oil based on the prevailing daytime temperature in the area in which the engine is operated. The chart in figure is a guide to selection the proper crankcase oil.

IMPORTANT: Oils containing “solid” additives, non-detergent oils, or low-quality oils are not recommended for use in G420F(E) Engine.



Engine Oil Viscosity Recommendation

NOTE: In normal case, the recommended engine oil for G420F(E) engine is SAE 10W - 30.

But, if the excessive valve noise occurs up to five minutes after a cold start and if the maximum ambient temperature is lower than 10°C (50°F), it is recommended to change engine oil to SAE 5W - 30 for that application.

Synthetic Oils

Synthetic engine oils are not recommended for use in G420F(E) Engine. Synthetics may offer advantages in cold-temperature pumpability and high-temperature oxidation resistance.
However, synthetic oils have not proven to provide operational or economic benefits over conventional petroleum-based oils in G420F(E) Engine. Their use does not permit the extension of oil change intervals.

Lubrication System Problems

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

- Too much oil consumption.
- Low oil pressure.
- High oil pressure.
- Too much component wear.

Too Much Oil Consumption

• Engine outside oil leakage

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

• Combustion area oil leakage

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are three possible ways for oil leakage into the combustion area of the stems.

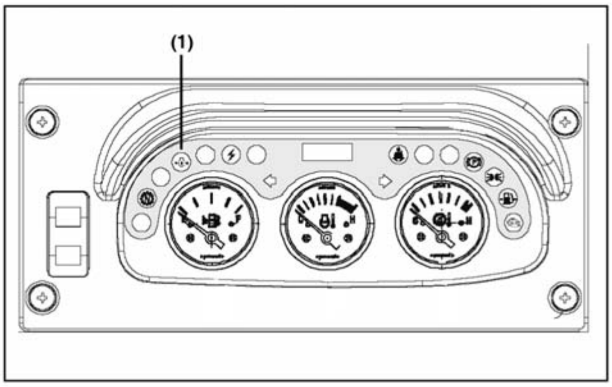
1. Oil leakage between worn valve guides and valve stems.

2. Worn or damaged piston rings, or dirty oil return holes.

3. Compression ring and/or intermediate ring not installed correctly.

NOTE: Too much oil consumption can also be the result if oil with the wrong viscosity is used. Oil with a thin viscosity can be caused by fuel leakage into the crankcase, or by increased engine temperature.

Low Oil Pressure



Instrument Panel

(1) Engine Oil Light

Before starting the engine, the engine oil light(1) on the instrument panel will turn on when the key switch is turned to the ON position. The light will turn off after the engine is started and while the engine is running, lidicating normal oil pressure. The light will turn on during operation only when there is insufficient engine oil pressure to properly lubricate the engine's internal parts.

If the oil light comes on, indicating the pressure is low, check for the causes that follow:

1. Low oil level in the crankcase.

2. Defect in the oil pressure indicator light or oil pressure sensor unit.

3. Restriction to oil pump screen.

4. Leakage at the oil line connections.

5. Worn connecting rod or main bearings. Worn gears in the oil pump.

6. Oil pressure relief valve worn or stuck in the OPEN position.

7. Oil filter bypass valve stuck open. Oil filter is restricted. Replace oil filter.

High Oil Pressure

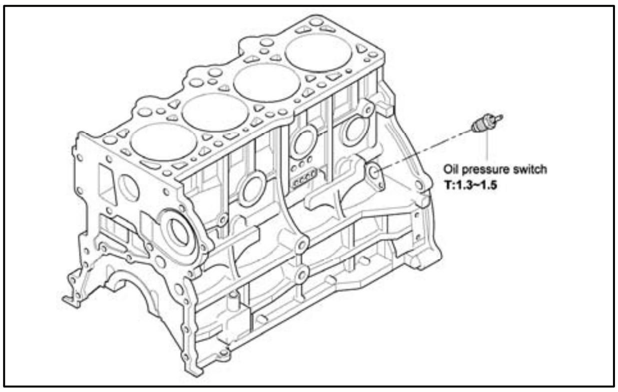
Oil pressure will be high if the oil pressure relief valve in the oil pump cannot move from the closed position.

Too Much Component Wear

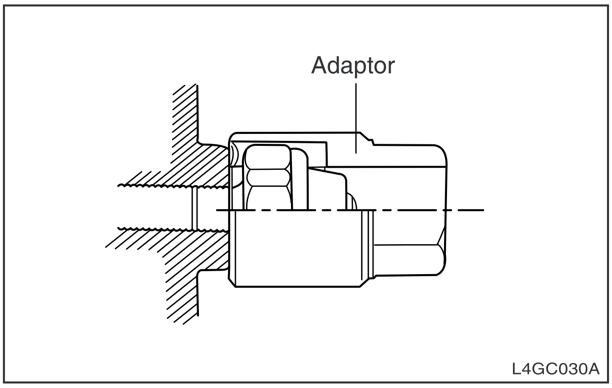
When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage. A broken oil passage can also be the cause.
If an oil pressure check is done and the oil pressure is correct, but a component is worn because it does not get enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

Oil Pressure Switch

Oil pressure switch is located on the front right side of the engine and if oil pressure in the lubrication system drops less than 0.29kg/cm2, the oil pressure warning lamp illuminates. Hexagonal width of this switch is 24mm.



Removal and Installation

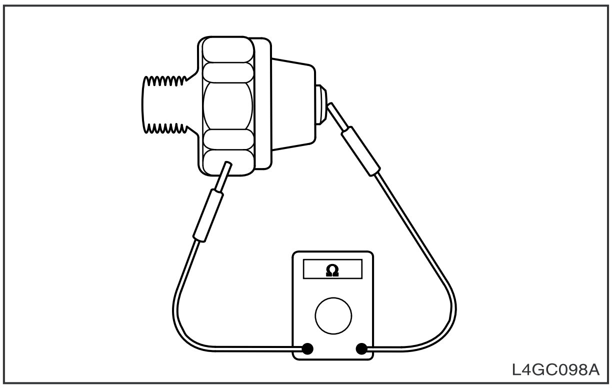


After applying sealant to the spiral portion, install the oil pres-sure switch.

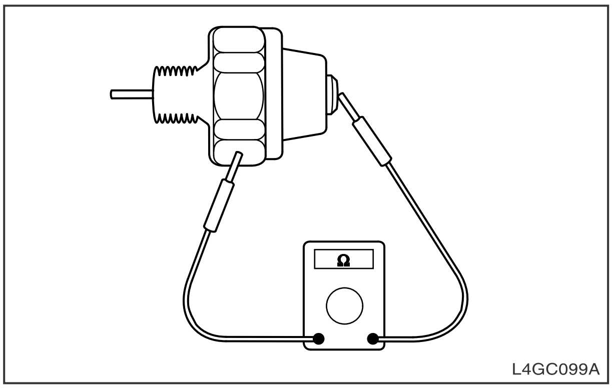
NOTE: Do not tighten the oil pressure switch too tight.

Oil pressure switch	1.3 ~ 1.5㎏·m

Inspection



1. Using an ohmmeter, measure an electric current and re-place the oil pressure switch if an electric current is not detected.

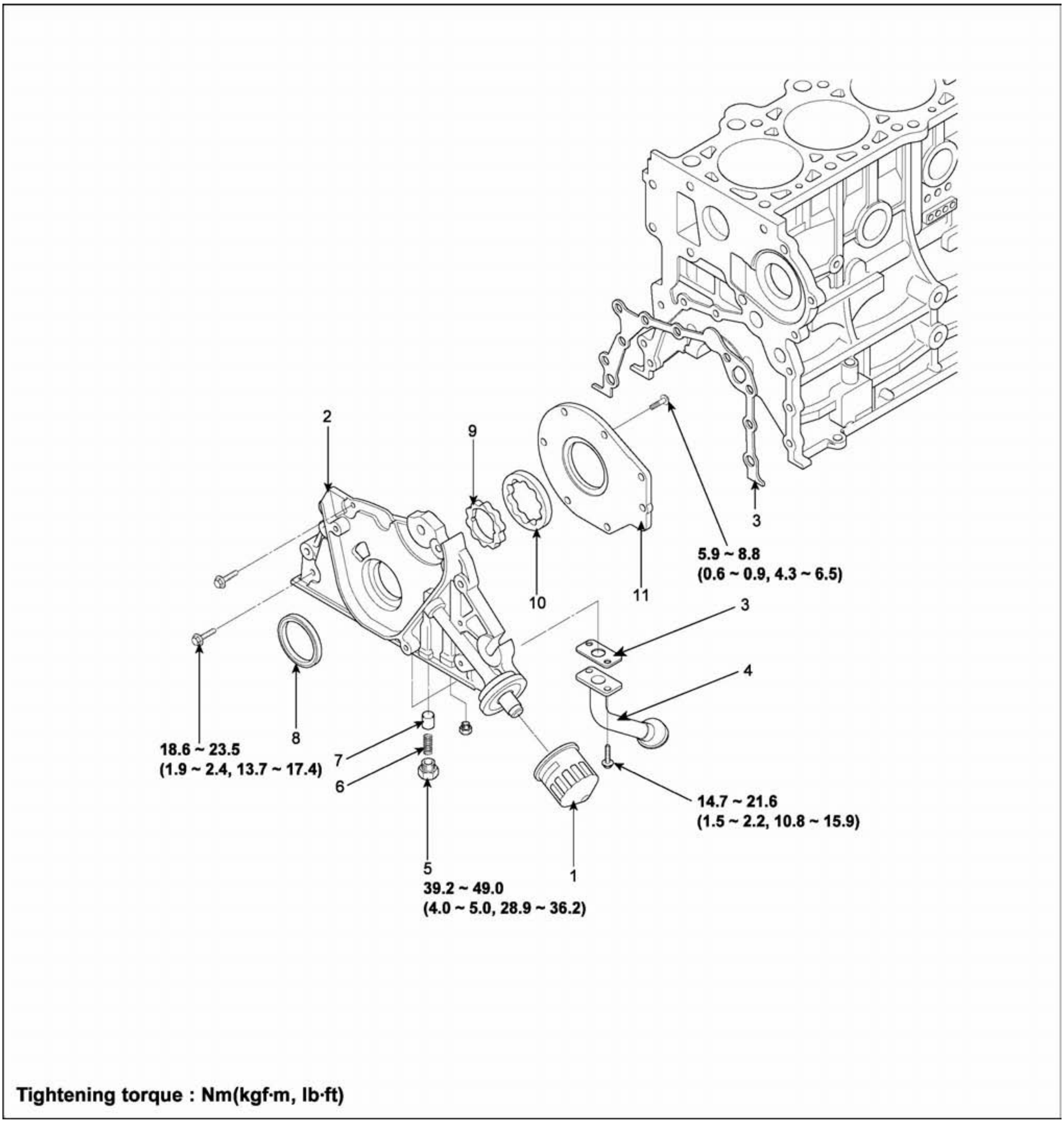


2. When pressing it with a thin stick, if an electric current is measured between terminal and body, replace the oil pres-sure switch.

3. When applying a negative pressure of 0.3kg/cm2 through the oil hole, it an electric current is not measured, the switch is normal. If the switch is not normal, check for air leak. If air is leaked, replace the switch because it means damage of the diaphragm.

Front Case and Oil Pump

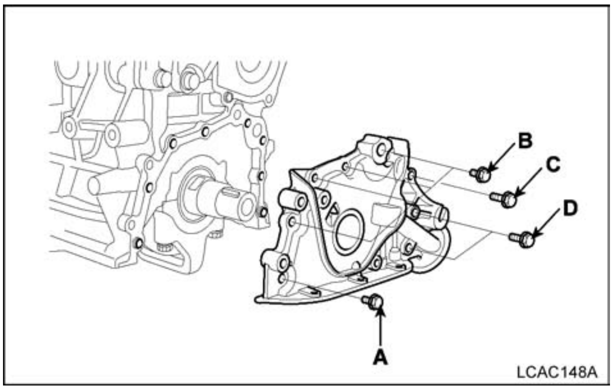
COMPONENTS



1. Filter
2. Front case
3. Gasket
4. Oil screen
5. Plug
6.Relief spring

7.Relief plunger
8.Oil seal
9.Inner rotor
10.Outer rotor
11.Pump cover

REMOVAL



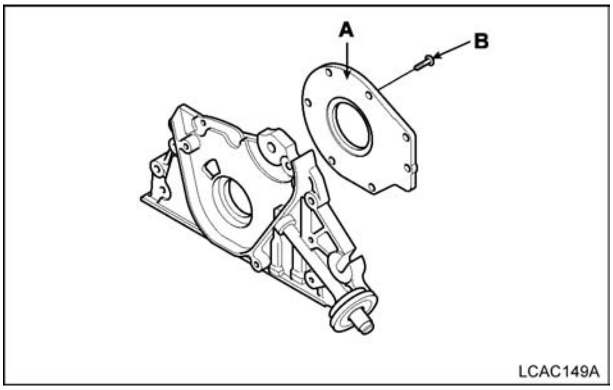
1. Drain engine oil.

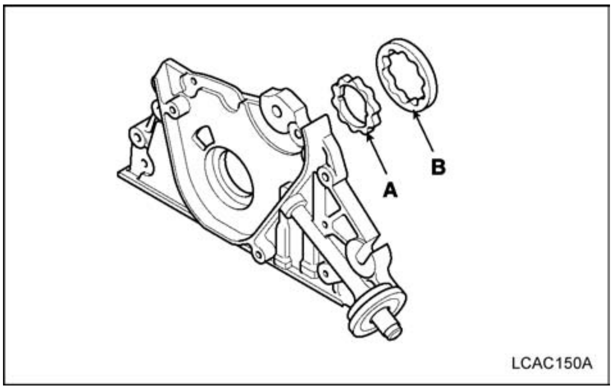
2. Remove the drive belts.

3. Turn the crankshaft and align the white groove on the crank-shaft pulley with the pointer on the lower cover.

4. Remove the timing belt.

5. Remove the oil pan and oil screen



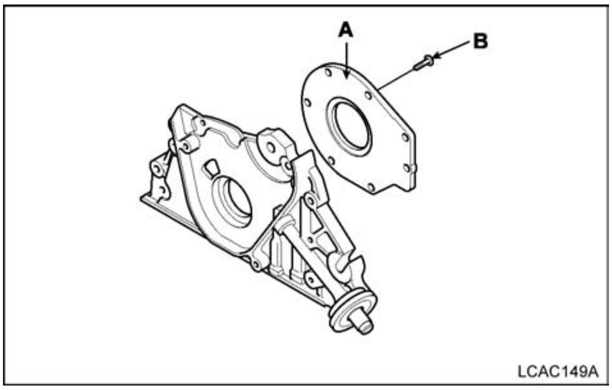


6. Remove the front case.

1) Remove the screws (B) from the pump housing, then separate the housing and cover (A).

2) Remove the inner (A) and outer (B) rotos.

INSPECTION

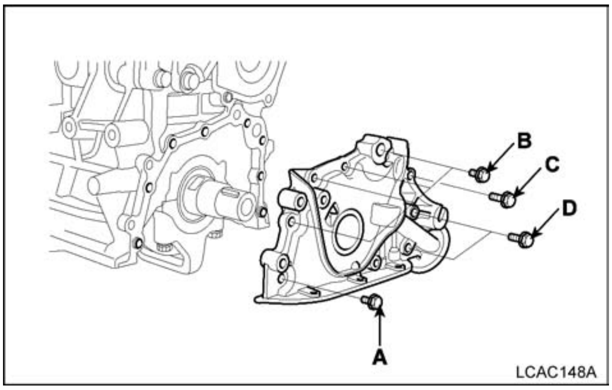


1. Install oil pump.

1) Place the inner and outer rotors into front case with the marks facing the oil pump cover side.

2) Install the oil pump cover (A) to front case with the 7screws (B).

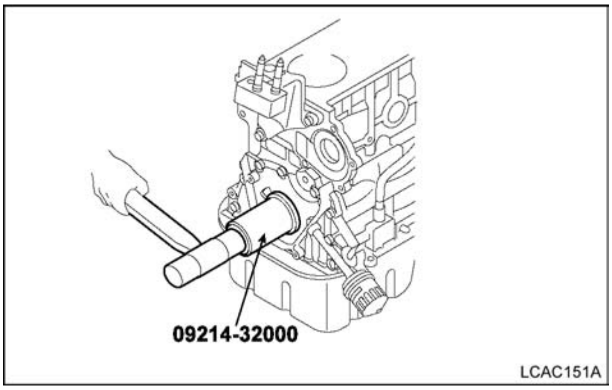
Tightening torque	5.9~8.8N.m
	(0.6~0.9kgf.m, 4.3~6.5lb-ft)



2. Check that the oil pump turns freely.

3. Install the oil pump on the cylinder block.
Place a new front case gasket on the cylinder block. Apply engine oil to the lip of the oil pump seal. Then, install the oil pump onto the crankshaft. When the pump is in place, clean any excess grease off the crankshaft and check that the oil seal lip is not distorted.

Body length	A	25mm(0.98in)
	B	20mm(0.787in)
	C	38mm(1.496in)
	D	45mm(7.771in)
Tightening torque		19.6~26.5N.m
		(2.0~2.7kgf.m, 14.5~19.5lb-ft)



4. Apply a light coat of oil to seal lip.

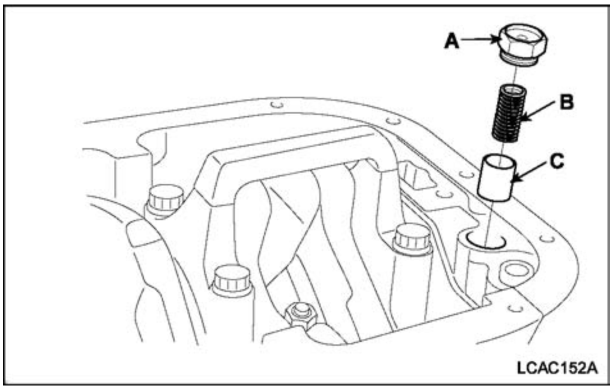
5. Using the SST(09214-32000), install the oil seal.

6. Install the oil screen.

7. Install the oil pan.

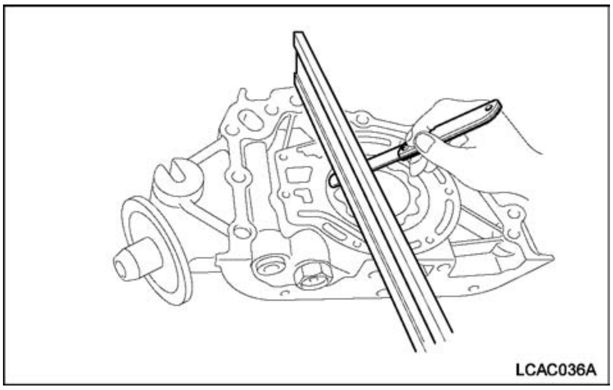
NOTE: Clean the oil pan gasket mating surfaces.

DISASSEMBLY



1. Remove the relief plunger.
Remove the plug (A), spring (B) and relief plunger (A).

INSPECTION



1. Inspect relief plunger.
Coat the valve with engine oil and check that it falls smoothly into the plunger hole by its own weight.
If it does not, replace the relief plunger. If necessary, replace the front case.

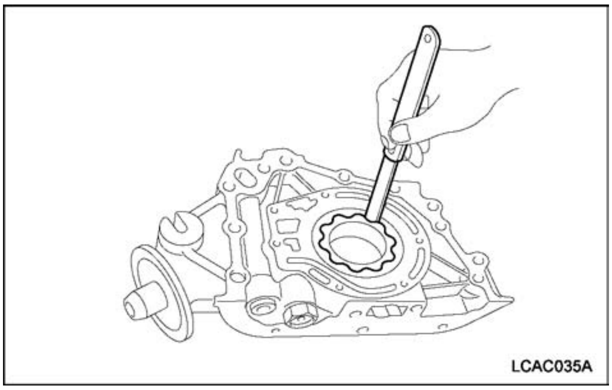
2. Inspect relief valve spring.
Inspect for distorted or broken relief valve spring.

Standard value	Free height	43.8mm
		(1.724in.)
	Load	3.7kg/40.1mm
		(8.14lb/1.579in.)

3. Inspect rotor side clearance.
Using a feeler gauge and precision straight edge, measure the clearance between the rotos and precision straight edge.

Side clearance	Outer gear	0.04~0.09mm
		(0.0016~0.0035in.)
	Inner gear	0.04~0.085mm
		(0.0016~0.0033in.)

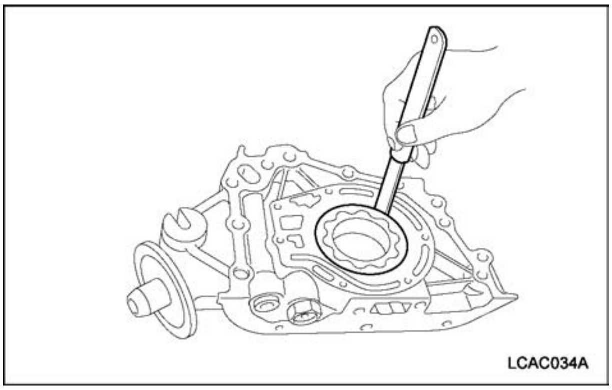
If the side clearance is greater than maximum, replace the rotors as a set. If necessary, replace the front case.



4. Inspect rotor rip clearance.
Using a feeler gauge, measure the tip clearance between the inner and outer rotor tips.

Tip clearance	0.025~0.069mm (0.0010~0.0027in.)

If the tip clearance is greater than maximum, replace the rotor as a set.

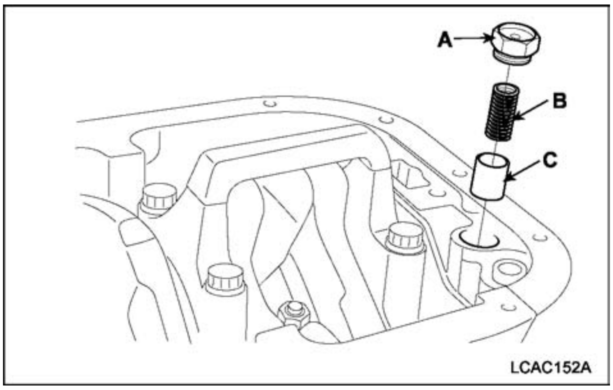


5. Inspect rotor body clearance.
Using a feeler gauge, measure the clearance between the outer rotor and body.

Body clearance	0.12~0.185mm (0.0047~0.0073in.)

If the body clearance is greater than maximum, replace the rotor as a set. If necessary, replace the front case.

REASSEMBLY

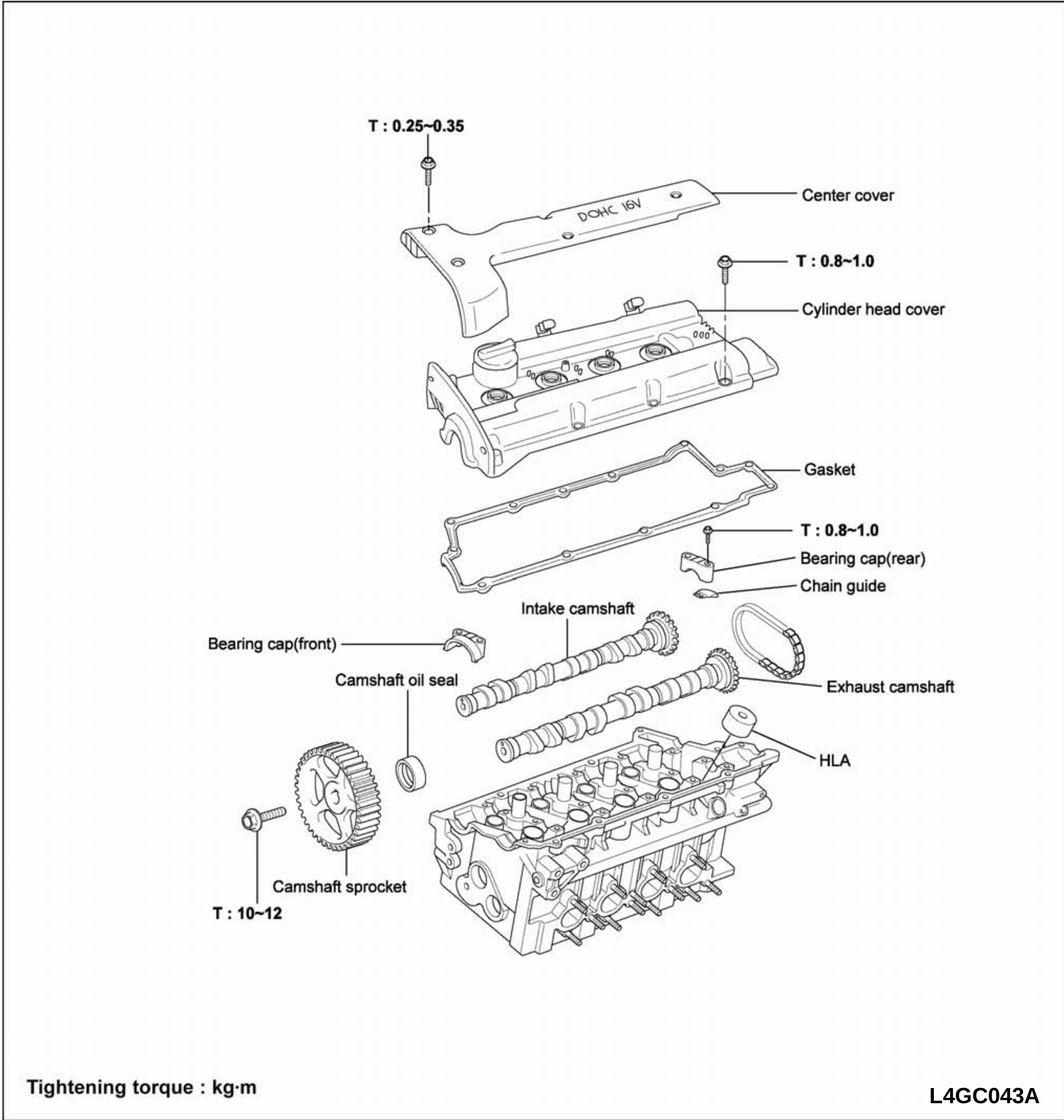


1. Install relief plunger.
Install relief plunger (A) and spring (B) into the front case hole, and install the plug(A).

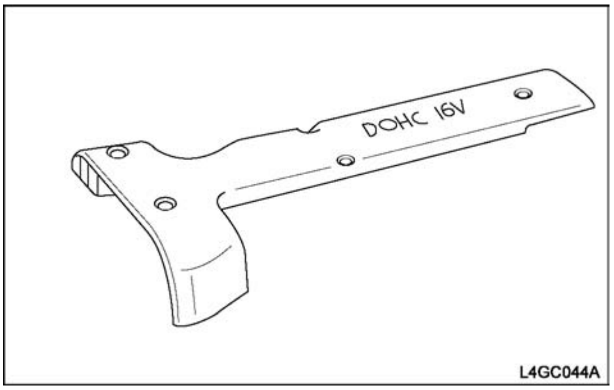
Tightening torque	39.2~49.0kgf.m (28.9~36.2lb-ft)

CAM Shaft, HLA, Timing Chain

Components



Removal



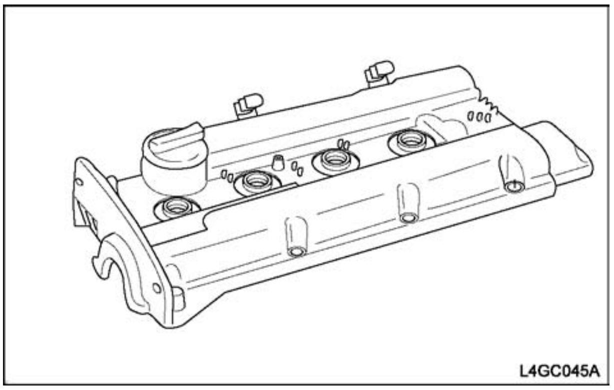
L4GC044A

1. Remove the breather hose and P.C.V hose.

2. Remove the center cover.

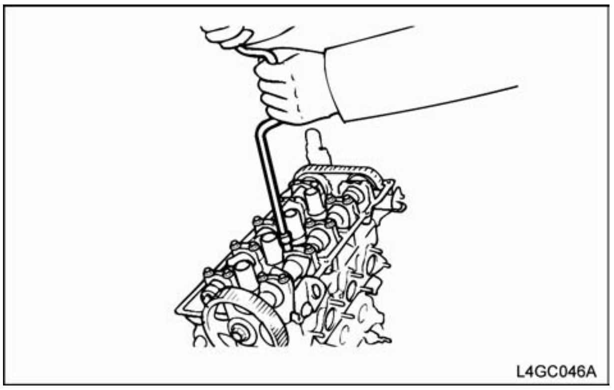
3. Remove the ignition coil.

4. Remove the timing belt upper cover.



L4GC045A

5. Remove the cylinder head cover.



L4GC046A

6. Remove the tensioner.

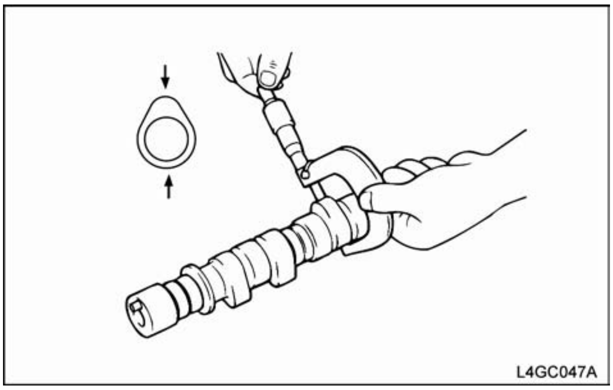
7. Loosen the camshaft sprocket bolt and remove the cam-shaft sprocket.

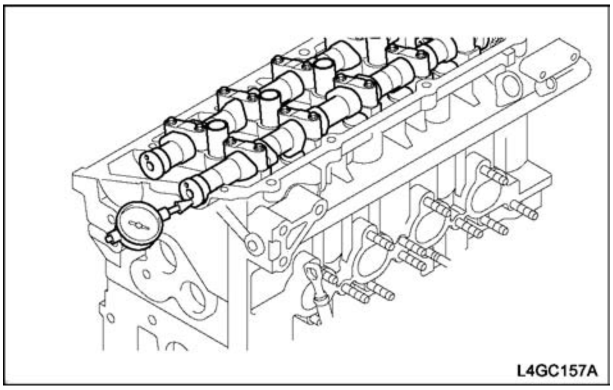
8. Loosen the bearing cap bolt and after removing the bear-ing cap, remove the camshaft.

9. Remove the timing chain.

10. Remove the HLA.

Inspection





Camshaft

1. Check the camshaft journal for wear and if the journal is seriously worn, replace the camshaft.

2. Check the cam lobe for damage and if the lobe is severely damaged or worn, replace the camshaft.

Items		Standard	Limit
Cam height	Intake	43	42.9
	Exhaust	43	42.9

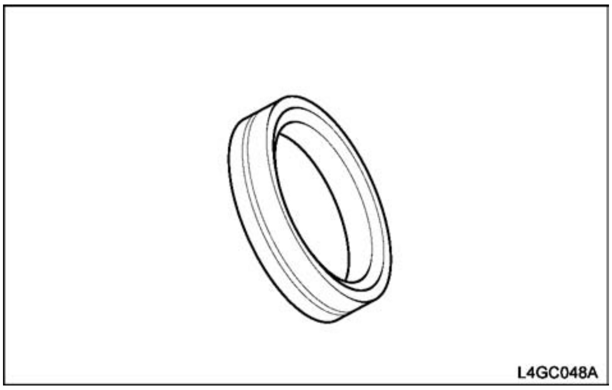
3. Check the cam surface for abnormal wear and damage and replace it if necessary.

4. Check the cylinder head camshaft journal for damage and if the surface is severely damaged, replace the cylinder head assembly.

5. Lightly put the camshaft on the cylinder head as shown in the illustration and after installing a dial gauge towards shaft, check the endplay.

Camshaft endplay	0.1 ~ 0.2mm

Oil Seal



1. Check the oil seal surface for wear and if the seal lip portion is worn, replace it.

2. Check the camshaft oil seal lip contact surface for partial wear and replace it if necessary.

HLA(Hydraulic Lash Adjuster)

1. HLA O.D : Ø33(-0.025/-0.041)mm

2. How to remove noise when it heard from valve

1) Prior to engine warm-up, check that the engine oil level is normal.

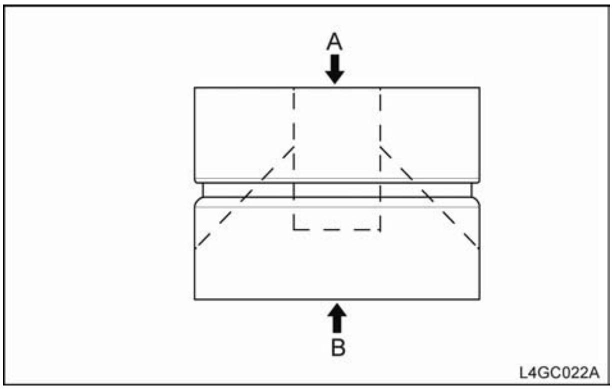
2) Warm-up the engine.

3) If the valve noise is heard at engine warm-up, air-bleed the system.

4) How to air-bleed

a) During remaining it for 10 minutes at 3,000 rpm and over 5 minutes at idle, check that the valve noise is heard.

b) Repeat the above step(a) only once or twice.



5) If the valve noise is still heard after following the above step 4), replace the hydraulic lash adjuster(HLA) which makes noise.

6) If the valve noise is heard after replacing parts, necessarily repeat the above step 4).

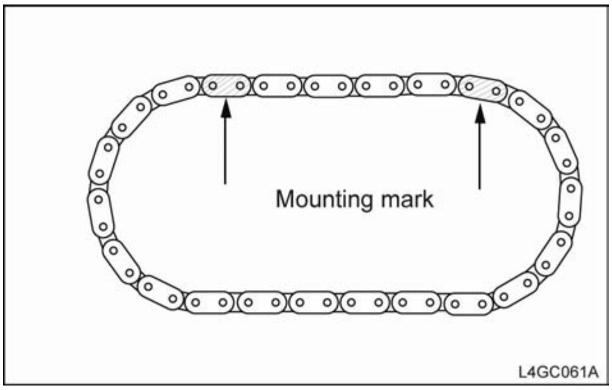
7) After air-bleeding the system and replacing parts to remove noise, if the valve noise is re-heard 2-3 days after, it might be affected from defective HLA, so replace the defective HLA.

NOTE: In case of the vehicle with HLA, when initially starting the engine, it is normal if valve noise is momentarily heard.

⚠ CAUTION

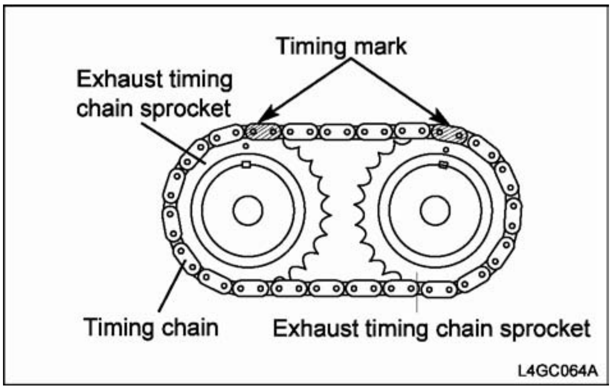
Because HAL is precision parts, take care not to come foreign materials such as a dust from outside.
Do not disassemble HLA.
When cleaning HLA, use clean diesel oil.
Take care not to make scratches and sharp edges to O.D of HLA.
With HLA filled with engine oil, grasp A and press B by hand as shown in the illustration, if the HLA is moving, replace the HLA.

Timing Chain



1. Check the timing chain bushing and plate portion for wear and if those are severely worn, replace those.

Installation

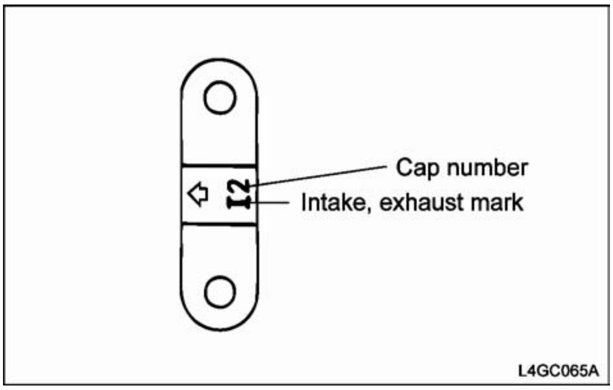


1. Install HLA

2. After Installing the intake and exhaust camshaft by aligning it with the timing mark on the timing chain sprocket, install the camshaft to the cylinder head.

⚠ CAUTION

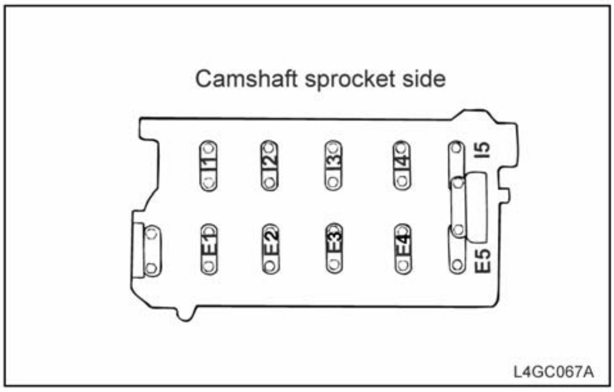
Apply engine oil to the camshaft journal and cam.
There a detective pin for TDC sensor in the intake camshaft rear end and a dowel pin in the intake camshaft front end.



3. Install the camshaft cap.
Check the intake and exhaust identification marks.(Check cap number and arrow and take care not to change the bearing cap position and direction.)

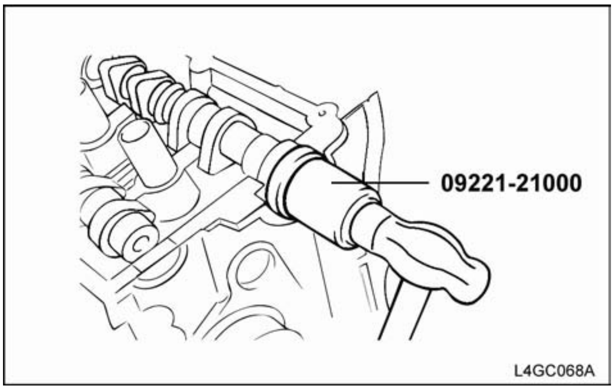
I: Intake cam shaft

E: Exhaust camshaft

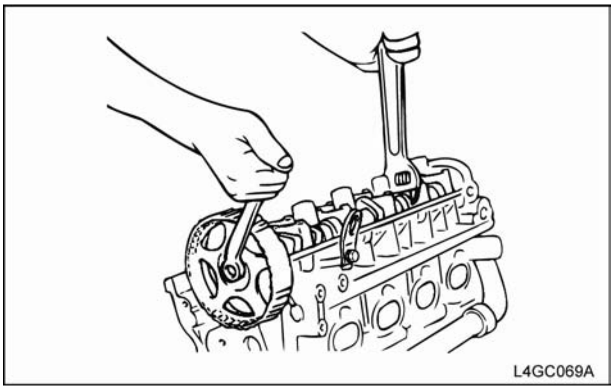


4. Tighten the bearing cap to the specified torque by tightening bolts 2-3 times as shown in the illustration.

Bearing cap bolt	1.4 ~ 1.5kg·m



5. Using the special tool camshaft oil seal installer and guide, press the camshaft oil seal.
Necessarily apply engine oil to the oil seal lip.
Insert the oil seal through the camshaft front end and install it by tapping on the installer with a hammer until the oil seal reaches 8.5mm from the camshaft front end.

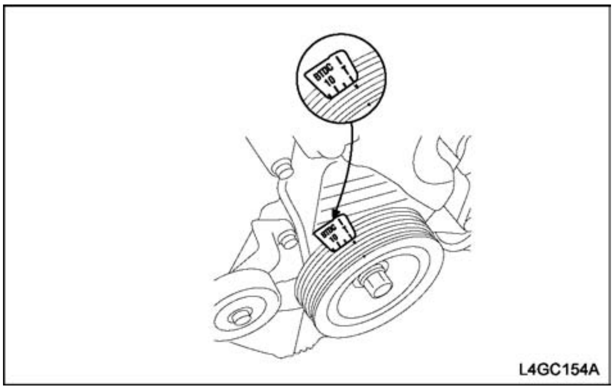


6. Install the camshaft sprocket to the specified torque.

Camshaft sprocket bolt	10 ~ 12kg·m

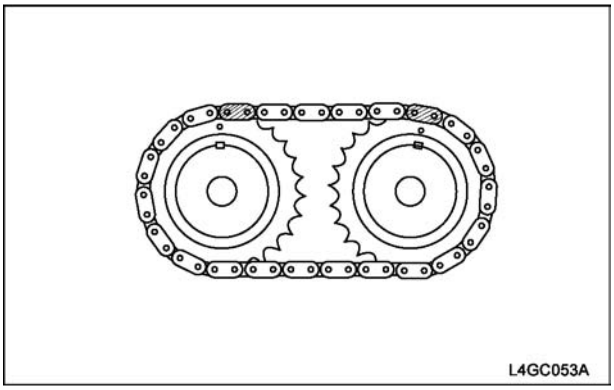
⚠ CAUTION

Align the timing marks on the camshaft sprocket and the crankshaft sprocket. At this time piston no.1 cylinder should be placed on the compression dead point.



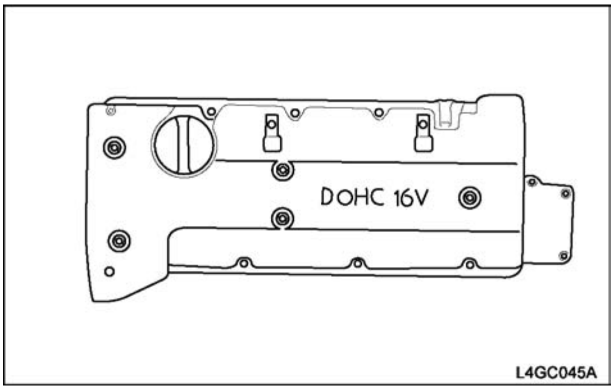
7. Place the cylinder no.1 to the dead point.

1) Rotate the crankshaft pulley so as to align it with “T” mark on the timing belt low cover.



2) Check that the camshaft timing pulley hole is aligned with timing mark on the bearing cap. If it is not aligned, readjust it by rotate the crankshaft to360°.

8. Assembly the timing belt.



9. Install the cylinder head cover. Apply sealant as shown in the illustration.

Cylinder head cover	0.8 ~ 1.0kg·m

Apply engine oil to the oil seal lip to help install the cylinder head cover oil seal to the spark plug pipe smoothly.

⚠ CAUTION

Necessarily tighten the cylinder head cover bolt to the specified torque.
If it is tightened too much, the head cover can be deformed resulting in oil leaks and the head cover bolt can be broken resulting in cylinder head replacement.
When installing after head cover removing, necessarily apply sealant to the head cover rear and front portion.
Because the head cover is made of plastic, take care not to drop tools on the head cover upper portion when removing/installing the engine parts.
When installing after head cover removing, after checking the head gasket for damage, re-use it if it is normal.
When applying/draining engine oil, take care not to spill oil on the head cover upper surface, if oil is spilled, wipe it out completely with a paper and a rag.

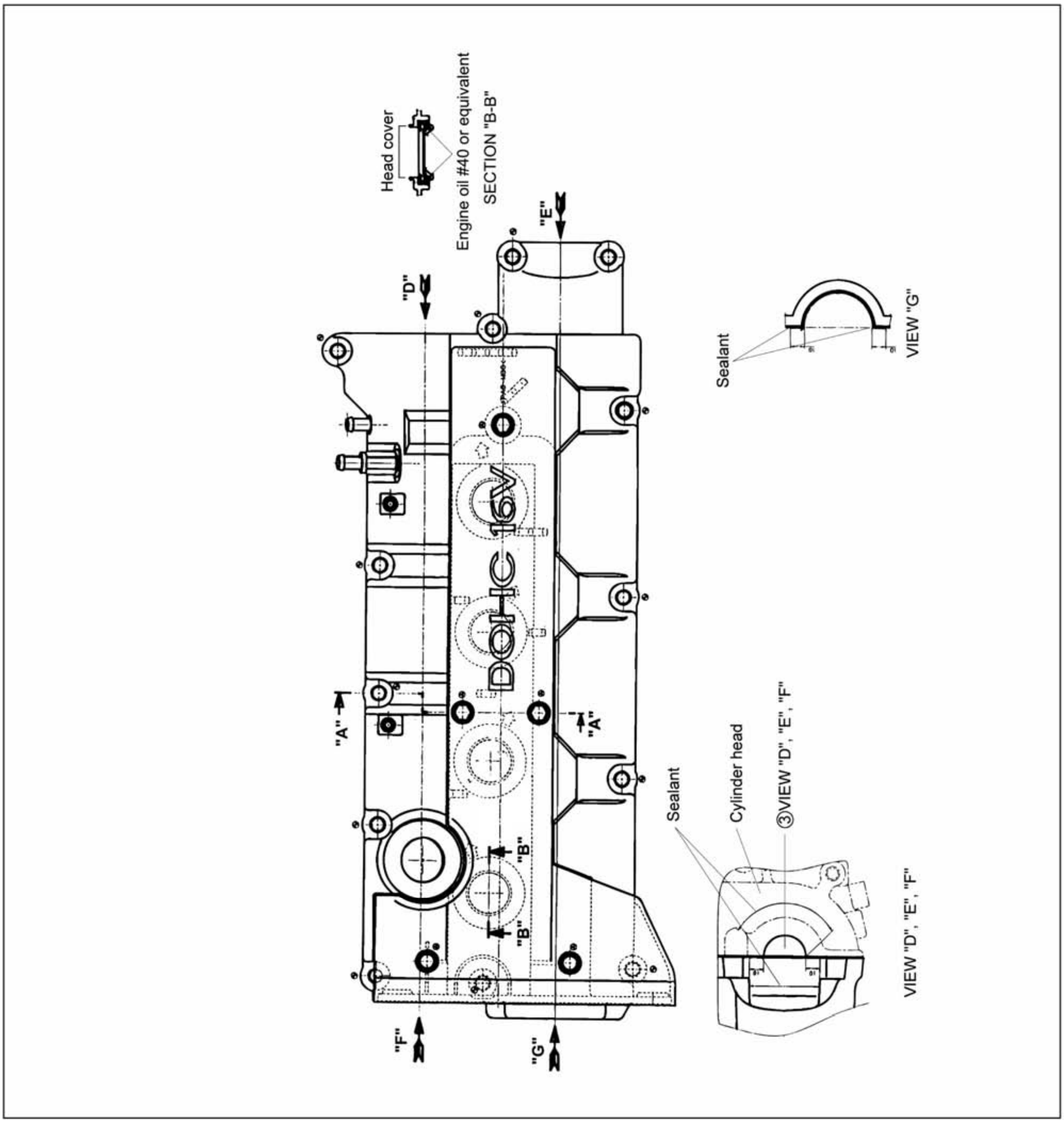
10. Install the timing belt cover.

Timing belt cover	0.8 ~ 1.0kg·m

11. Assembly the ignition coil.

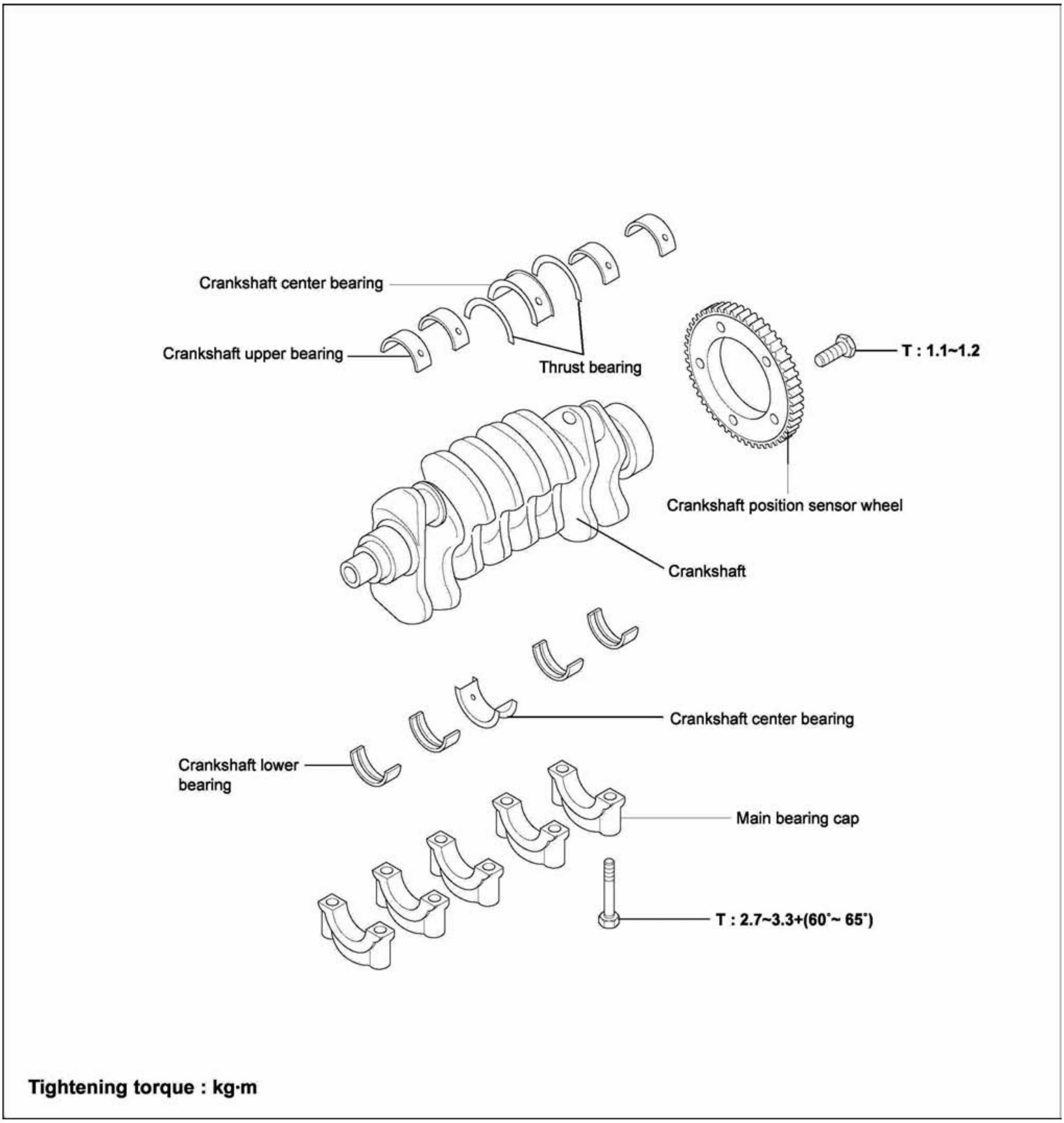
12. Install the spark plug center cover.

Center cover	0.25 ~ 0.35kg·m


Head cover
Engine oil #40 or equivalent
SECTION "B-B"
"D"
"E"
"A"
"B"
"F"
"G"
Sealant
VIEW "G"
Sealant
Cylinder head
③VIEW "D", "E", "F"
VIEW "D", "E", "F"

Crankshaft

Components



Disassembly

1. Remove the timing belt train, front case, flywheel, cylinder head assembly, and oil pan.

2. Remove the rear oil seal.

3. Disconnect the connecting rod cap.

4. Remove the main bearing cap. (Arrange it in order)

5. Remove the crankshaft.

6. Disassemble the crankshaft position sensor wheel.

NOTE: Put an identification mark on the main bearing cap to refer to the original position and direction.

Inspection

1. Crankshaft

1) Check the oil hoe for clogging as well as crankshaft journal pin for damage, uneven wear and crack. Repair or replace parts if necessary.

2) Inspect out of circularity of the crankshaft journal taper and pin.

Crankshaft journal O.D	57mm
Crank pin O.D	45mm
Out of circularity of crankshaft journal pin	0.01mm or less

2. Main bearing and connecting rod bearing
Visually inspect each bearing for scratch, melting, sticking, and fault contact and replace the bearing if necessary.

3. Measuring oil clearance

1) Measure O.D of the crankshaft journal and pin.

2) Measure diameter of the crankshaft bore and connecting rod bore.

3) Measure the thickness of the crankshaft and connecting rod bearing.

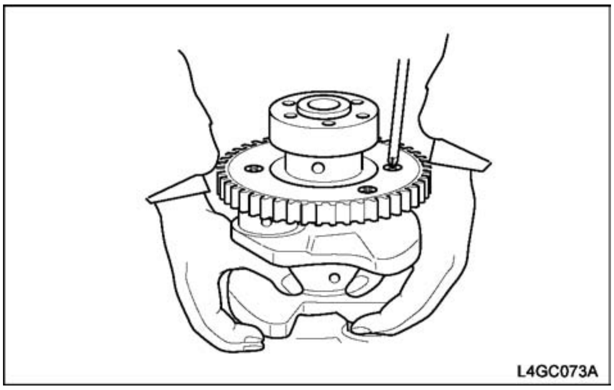
4) Calculate clearance by subtracting O.D of the journal pin and thickness of the bearing from diameter of the bore.

Journal oil clearance	0.028 ~ 0.048mm
Pin oil clearance	0.024 ~ 0.044mm

Main bearing cap bolt	2.7 ~ 3.3kg·m+ (60°~ 65°)
Connecting rod cap bolt	5.0 ~ 5.3kg·m

4. Oil seal
Check the front and rear oil seal and replace it with new parts if necessary.

Assembly



1. After checking the sensor wheel for damage and crack, replace it if necessary.

2. Inspect the clearance between the sensor wheel and crank position sensor.

Clearance between sensor wheel and crank position sensor	0.5 ~ 1.1mm

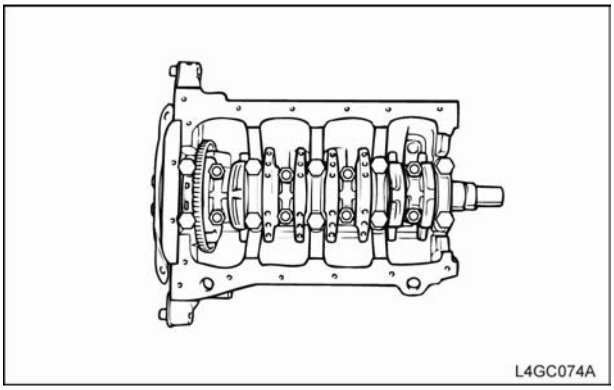
If the clearance is out of specified values, check the sensor wheel for balancing and the crank position sensor for installation and replace those if necessary.

⚠ CAUTION

Sensor wheel as one of the electronic control affects performance if deformed or damaged, so be careful when handling it.

3. Install the upper main bearing to the cylinder block. When reusing the main bearing, refer to the identification mark during assembly.

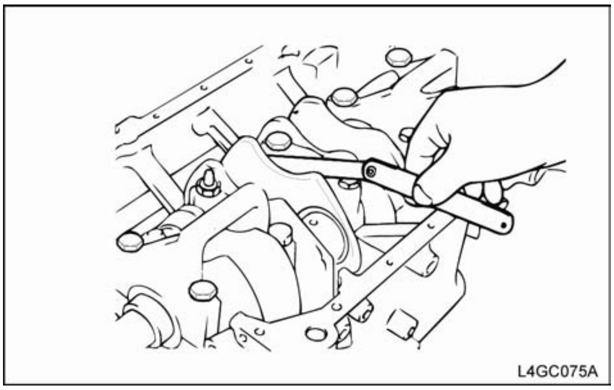
4. Install the bearing shaft and apply engine oil to the journal and pin.



5. Install the bearing cap and tighten the cap bolt to the specified torque from the center in order. (Tighten the bearing cap bolts to the specified torque by tightening bolts step by step 2-3 times equally)

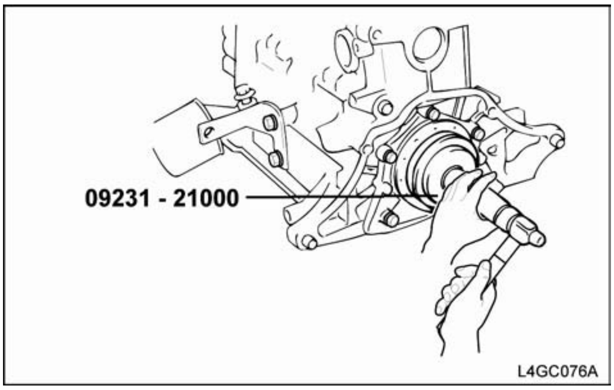
Main bearing cap bolt	2.7 ~ 3.3kg·m+ (60°~ 65°)
Connecting rod cap bolt	5.0 ~ 5.3kg·m

When installing the cap, proper number of cap should be installed as well as arrow mark should be directed to the engine crank pulley.



6. Check that the crankshaft for free rotation and proper clearance between the center main bearing thrust flange and connecting rod big-end bearing.

Crankshaft end-play	0.06 ~ 0.260mm



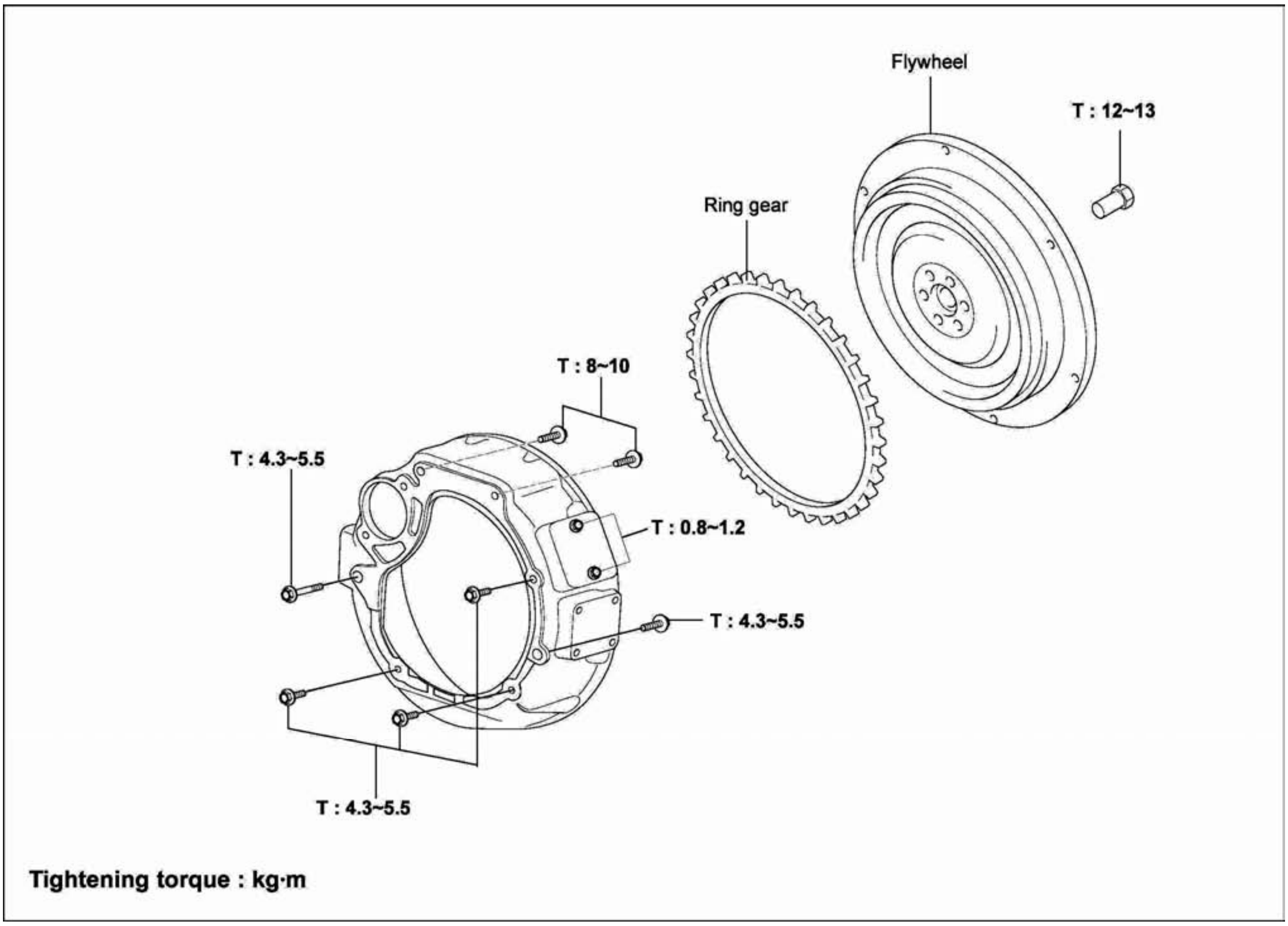
7. Using the special tool Crankshaft oil seal installer (09231-21000), fully insert the oil seal into the crankshaft rear oil seal case.

8. Install the rear oil seal case and gasket and tighten 5 bolts.
When installing, apply engine oil to the oil seal round and crankshaft.

9. Install the flywheel, front case, oil pan, and timing belt train.

Flywheel and Housing

Components



Removal

1. Remove the flywheel.

2. Remove the flywheel housing.

Inspection

1. Check the ring gear for damage and crack and replace it if necessary.

Assembly

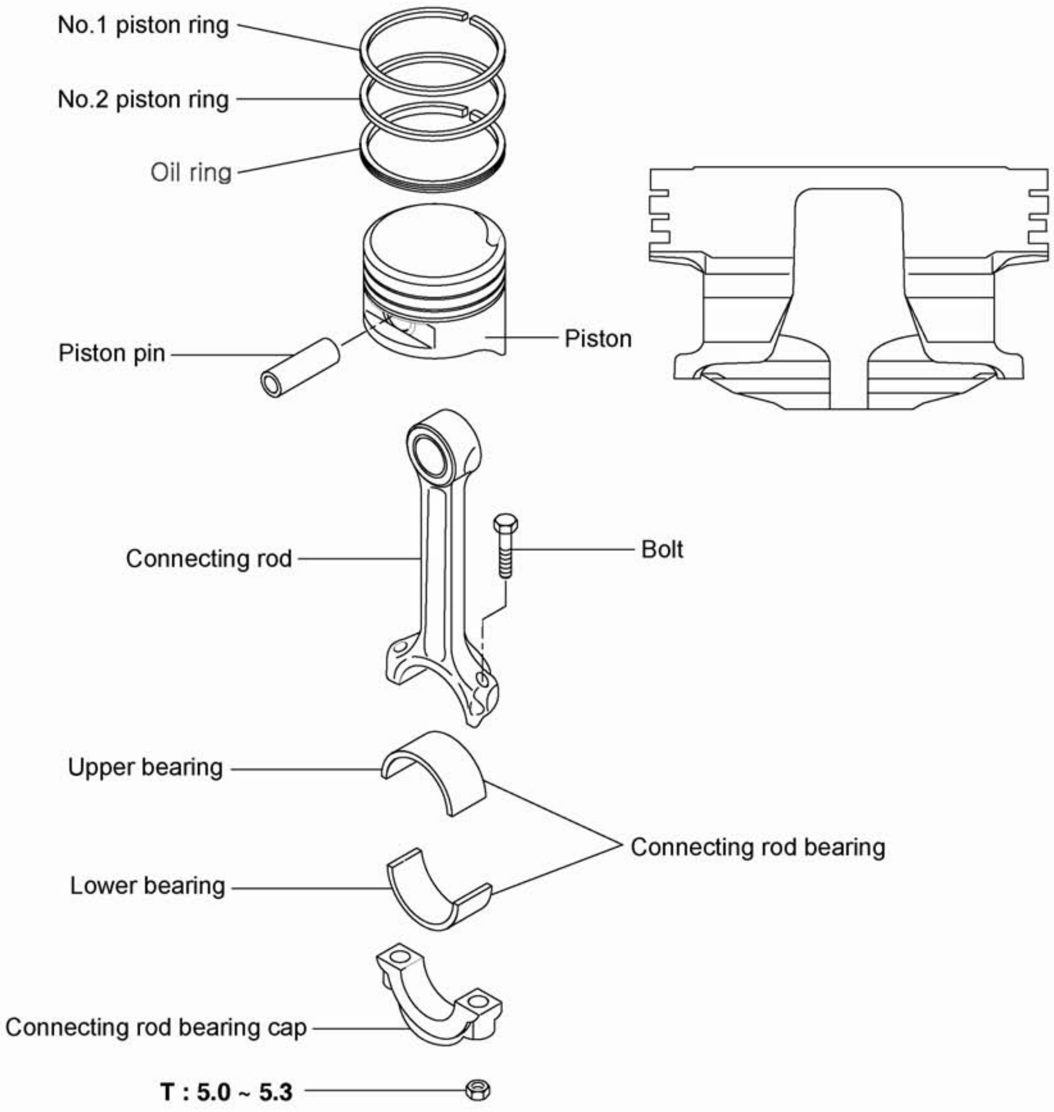
1. Install the flywheel housing and tighten the bolt to the specified torque.

2. Install the flywheel assembly and tighten the bolt to the specified torque.

Flywheel bolt	12 ~ 13kg·m

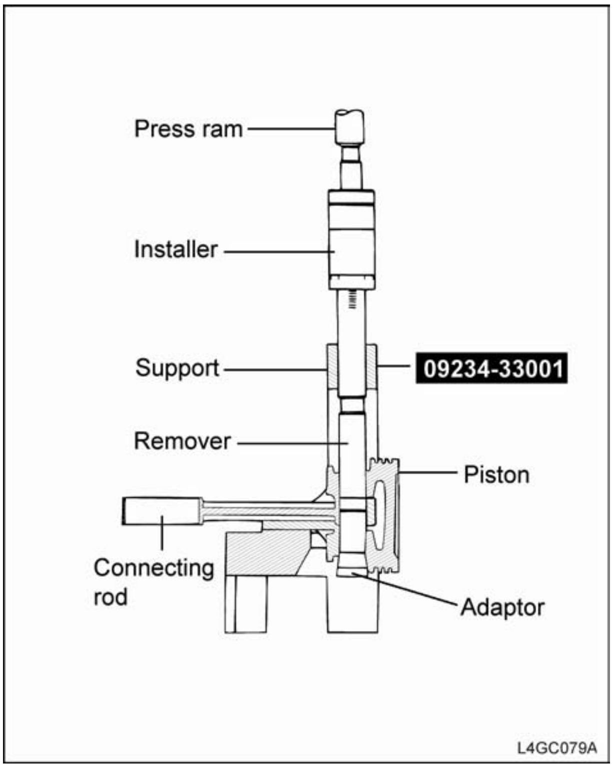
Piston and Connection Rod

Components



Tightening torque : kg·m

Disassembly



1. Remove the cylinder head assembly.

NOTE: Put an identification mark on the connecting rod and cap before disassembly to refer to the original position and direction.

2. Remove the oil pan and remove the oil screen.

3. After removing the connecting rod cap, remove the piston and connecting rod assembly from the cylinder. Arrange the connecting rod bearing in cylinder number order.

4. Using the special tool piston pin setting tool (09234-33001), disassemble the piston from the connecting rod as below.

1) Remove the piston ring.

2) When placing the assembly on a press, face the front mark on the piston upward.

3) Using the press, remove the piston pin.

Inspection

Piston and Pistonpin

1. Check the piston for scratch, wear, etc. and replace it if necessary.

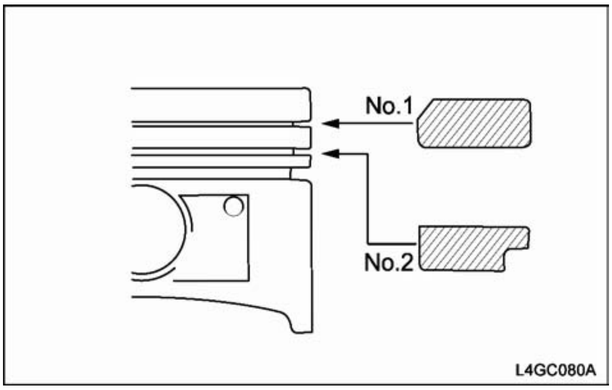
2. Check the piston ring for break, damage and abnormal wear and replace it if necessary. When replacing the piston, the ring should be replaced also.

3. Check that the piston pin is inserted in the piston hole and replace the piston and pin if necessary. Piston should be smoothly pressed at normal room temperature.

Piston Ring

1. When measuring the side clearance of piston ring, if the measured value is out of the limit, insert a new ring to the ring groove and re-measure the side clearance.

Item		Specified value	Limit
Side clearance of piston ring	No.1	0.04 ~ 0.08mm	0.1mm
	No.2	0.03 ~ 0.07mm	0.1mm



2. To measure the end gap of piston ring, insert the piston ring to the cylinder bore. At this time, smoothly insert the ring to the piston so as to place the ring and cylinder wall to right position. After this, smoothly insert the ring to the piston. And then, pull out the piston upward and measure gap using a feeler gauge. When the gap exceeds the limit, re-place the piston ring.

Item	Specified value	Limit
No.1 piston ring end gap	0.23 ~ 0.38	1mm
No.2 piston ring end gap	0.33 ~ 0.48	1mm
Oil ring end gap	0.20 ~ 0.60	1mm

When just replacing the ring without correction of cylinder bore, place the ring to the cylinder lower part where less worn-out and measure the gap.
When replacing the ring, use the same size of ring.

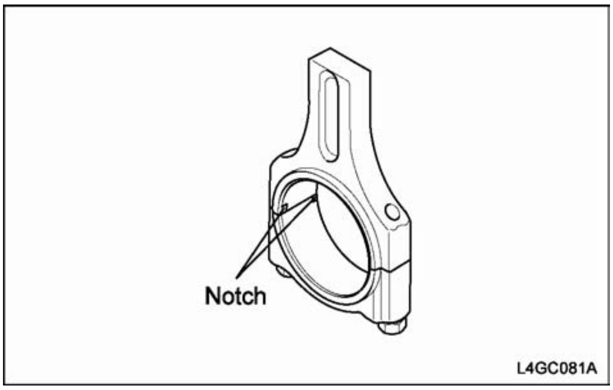
Item		Mark
Piston ring over size	STD	None
	0.25mm OS	25
	0.50mm OS	50
	0.75mm OS	75
	1.00mm OS	1.00

NOTE: Size mark is placed on the top of the ring.

Connecting Rod

1. When installing the connecting rod cap, refer to the cylinder numbers on the rod end cap which are marked during disassembly.
When installing a new connecting rod, align the bearing with the notch.

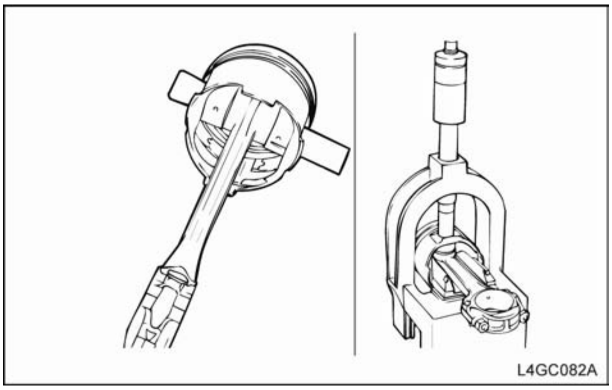
2. If both end thrust surfaces of the connecting rod are damaged, partially worn, or the inside of small end is too rough, replace the connecting rod.



3. Using a connecting rod aligner, measure bending and torsion of rod and if the measured value is around the limit, correct the rod with a press.
But when the rod is severely bended or damaged, necessarily replace it.

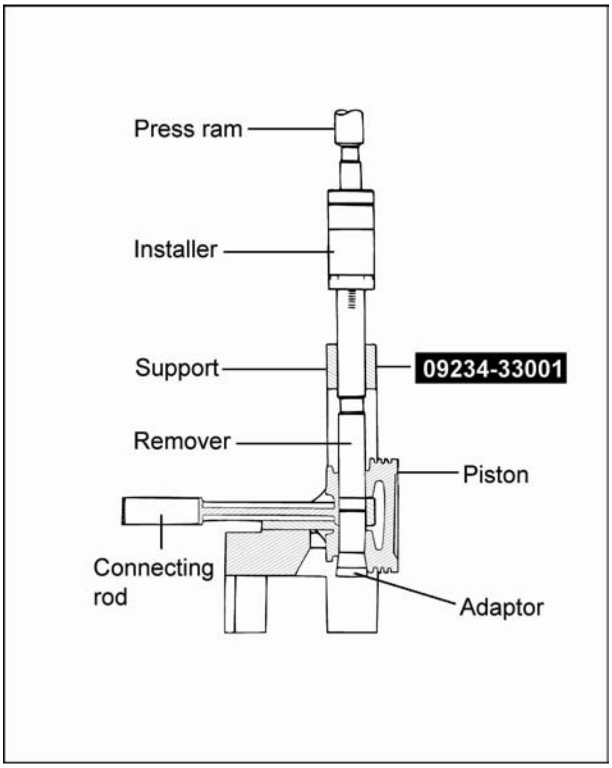
Bending of connecting rod	0.05mm
Torsion of connecting rod	0.1mm

Assembly



1. Using the special tool piston pin setting tool (09234-33001), assemble the piston and connecting rod as below.

1) Apply engine oil to the outer surface of the piston pin and small end bore of the connecting rod.



2) With the front mark faced upward, fix the connecting rod and piston and insert it into the piston pin assembly.

Front mark

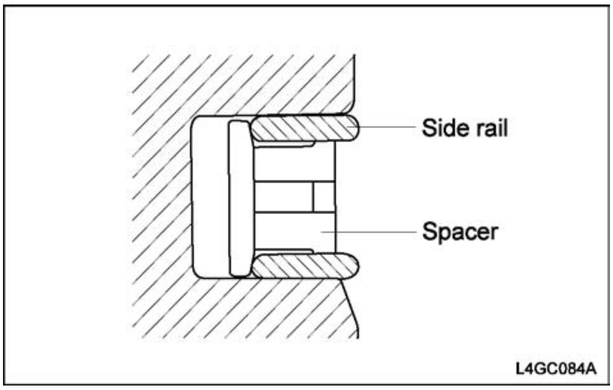
Piston side	0 (engraved)
Connecting rod side	Number (embossed)

3) Using a press, press-fit the piston pin into the pin hole with the specified pressure on the pin end through the push rod.
If the pressure is required more than the specified value, follow the next step.

Press-fit pressure of piston pin	350 ~ 1350kg

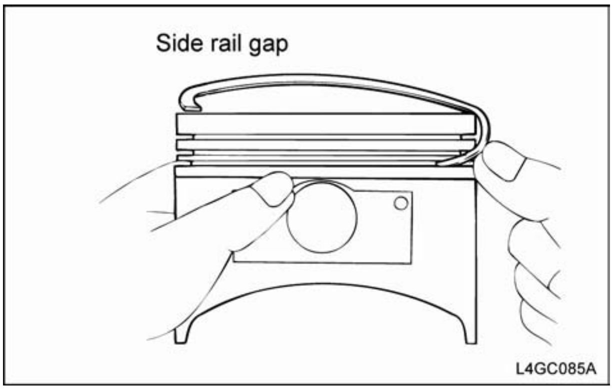
4) Rotate the push rod to a half turn, remove the piston connecting rod assembly from the support.

5) After press fitting the piston pin, check that the connecting rod for smooth slip and free movement.



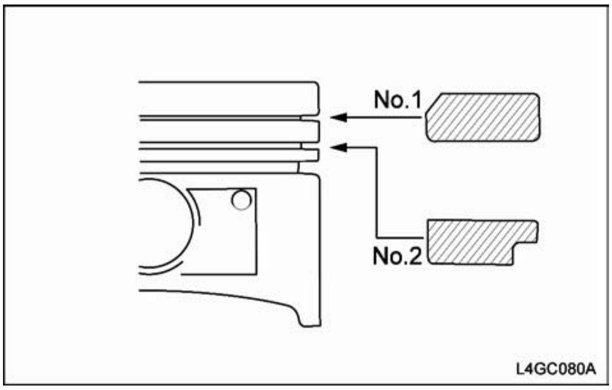
2. Install the piston ring to the piston in the following order.

1) Install 3 pieces of oil ring. Install the spacer lower side rail and upper side rail in order. When installing the side rail, do not use a piston ring expander to expand gap as usual because the side rail is broken. After placing one end of the side rail between the piston ring groove and spacer, grasp the lower side securely and press the side rail to the position by hand as shown in the illustration. At this time, after installing the lower side rail, install the upper side rail.



⚠ CAUTION

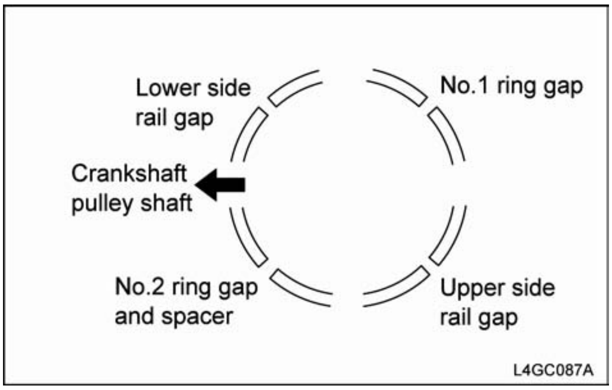
After installing 3 pieces of oil ring, check the upper and lower side rails for smooth rotation
The spacer expander gap should be away from the rail gap to 45° or more.

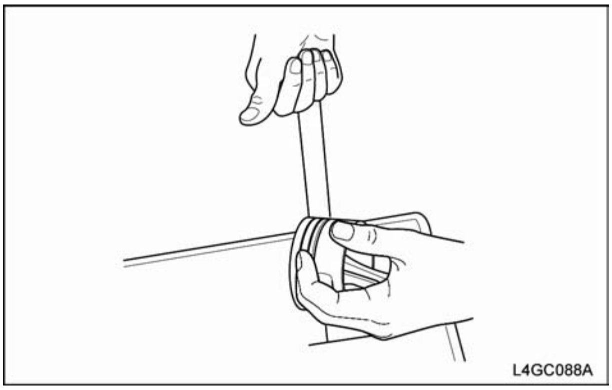


2) After installing no.2 piston ring, install no.1 piston ring.

⚠ CAUTION

Face the size mark and manufacturer mark on the ring surface upward when installing the piston ring
Take care not to change no.1 and no.2 piston rings.

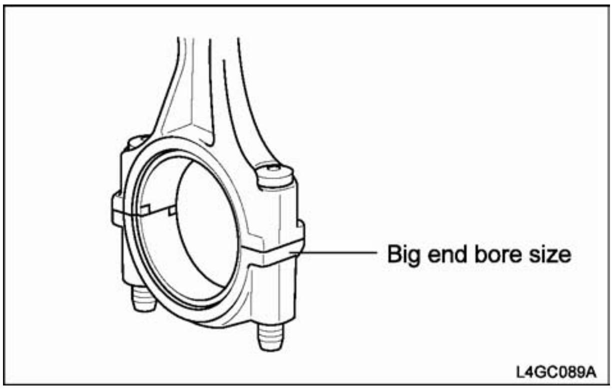




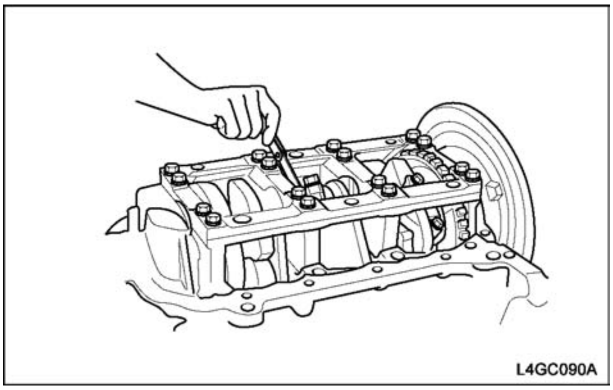
3. Using a piston ring clamp, insert the piston and connecting rod assembly as the cylinder number into the cylinder and face the arrow mark on the piston head toward the engine crankshaft pulley. Install a vinyl cover to the cap bolt not to damage the cylinder bore and crank pin.

⚠ CAUTION

Be sure that the piston ring gap is same as shown in the illustration. If the piston ring gap is normal, gaps are not aligned with direction of piston and thrust and each gap is away from gaps as far as possible.
Apply enough engine oil to the piston and piston ring round.



4. Install the connecting rod cap and tighten the cap nut to the specified torque. When installing the connecting rod cap, align the cylinder number on the connecting rod big end with cylinder number on the cap.



5. Inspect clearance of the connecting rod big end.

Clearance of connecting rod big end	0.1 ~ 0.25mm

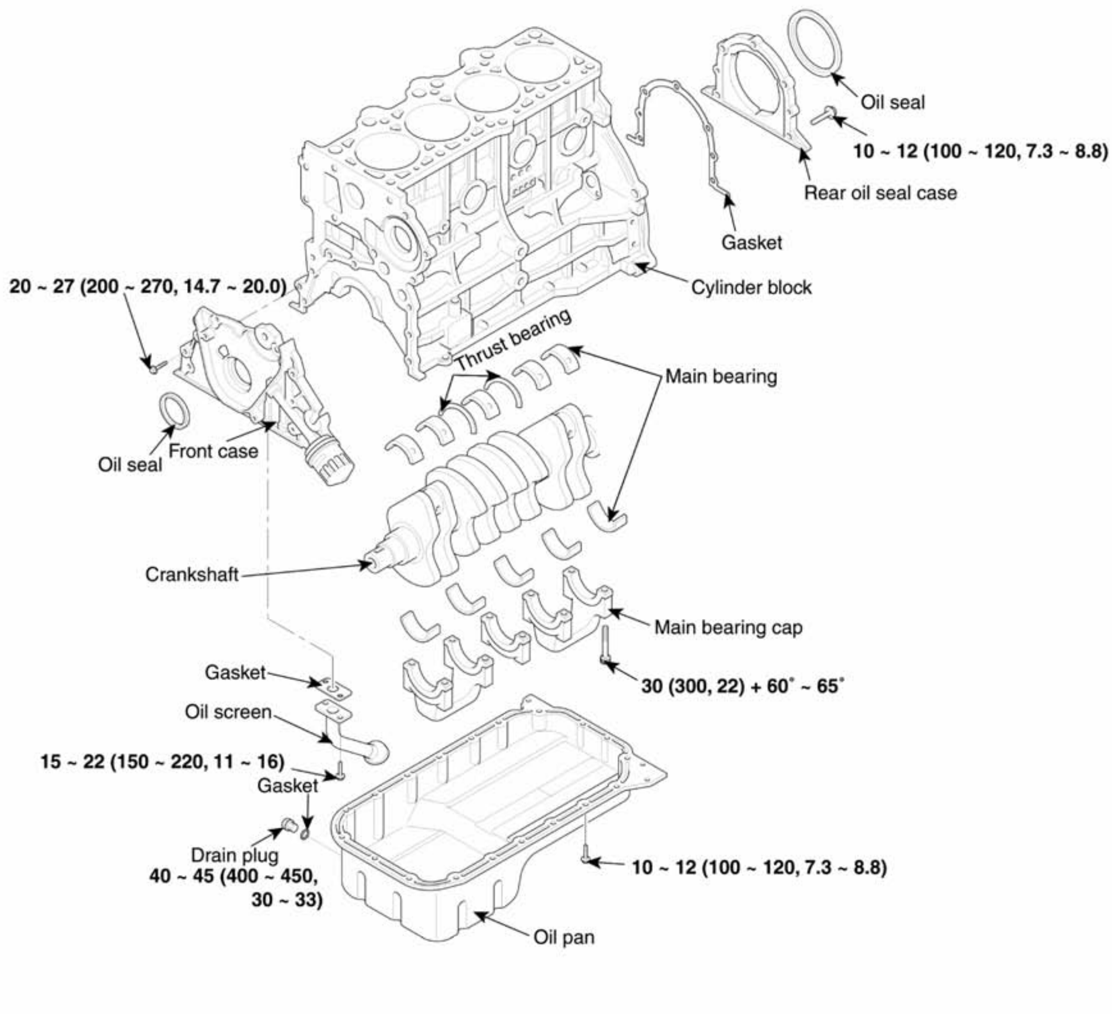
6. Install the oil screen.

7. Install the oil pan.

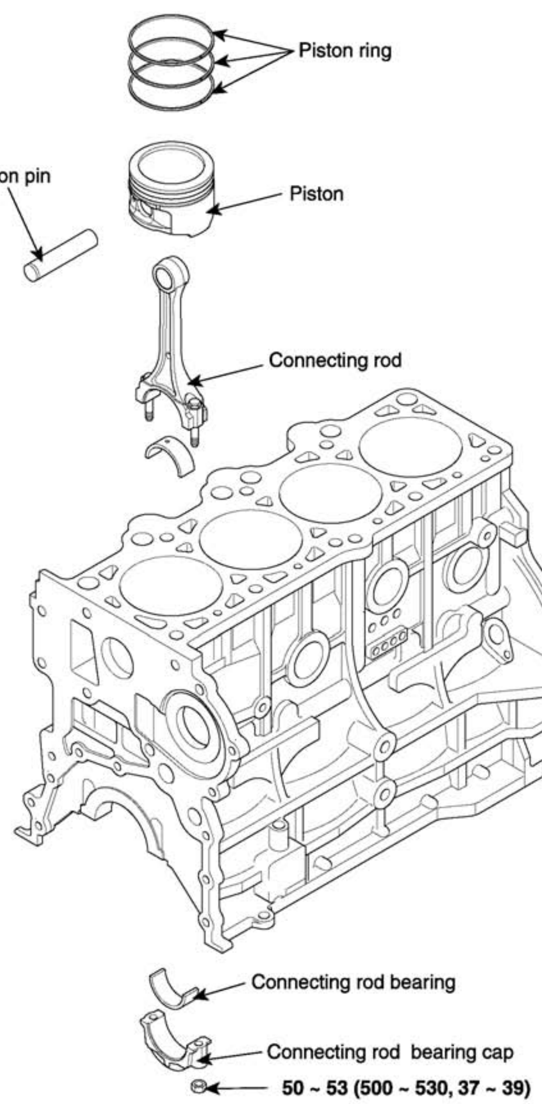
8. Install the cylinder head.

Engine Block

Component

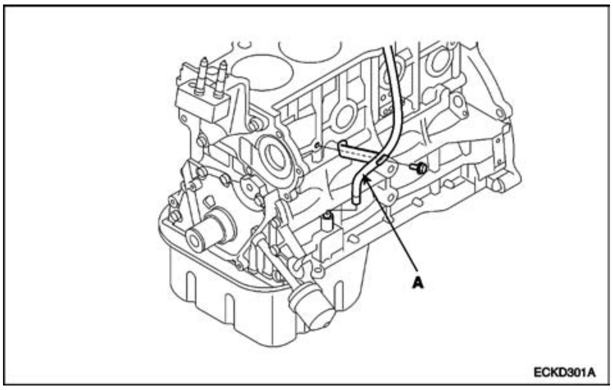


Tightening torque : N•m(kgf.cm , lbf•ft)



Tightening torque : N•m(kgf.cm , lbf•ft)

Disassembly



1. Remove flywheel.

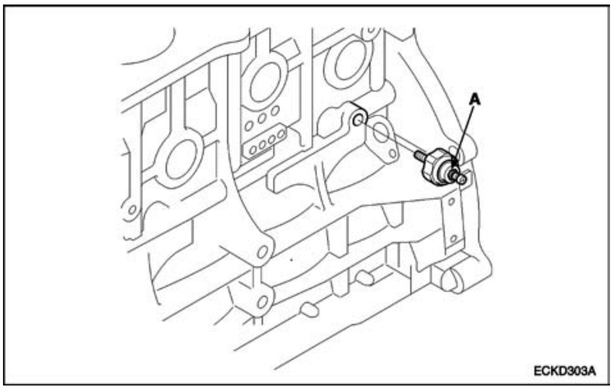
2. Remove flywheel housing.

3. Install engine to engine stand for disassembly.

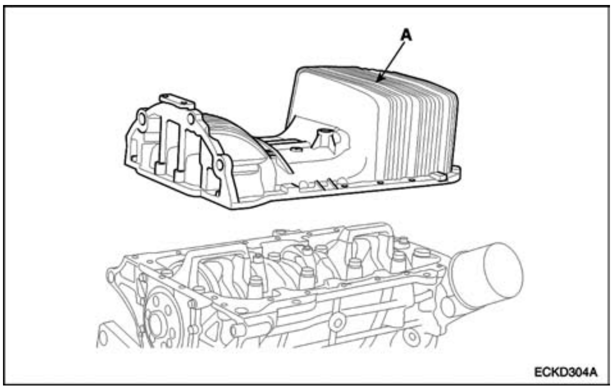
4. Remove timing belt.

5. Remove cylinder head.

6. Remove oil level gauge assembly (A).

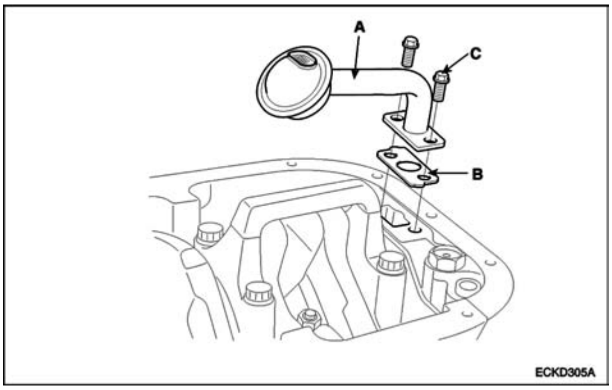


7. Remove oil pressure sensor (A).



8. Remove water pump.

9. Remove oil pan (A).



10. Remove oil screen.
Remove the 2bolts (C), oil screen (A) and gasket (B).

11. Check the connecting rod end play.

12. Remove the connecting rod caps and check oil clearance.

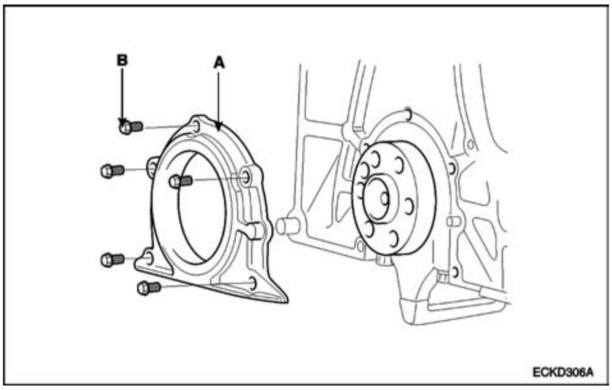
13. Remove piston and connecting rod assemblies.

1) Using a ridge reamer, remove all the carbon from the top of the cylinder.

2) Push the piston, connecting rod assembly and upper bearing through the top of the cylinder block.

NOTE: Keep the bearings, connecting rod and cap together. Arrange the piston and connecting rod assemblies in the correct order.

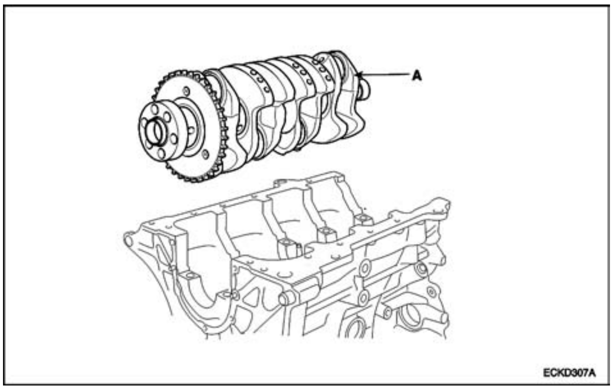
14. Remove front case.



15. Remove rear oil sealcase. Remove the 5bolts (B) and rear oil sealcase (A).

16. Remove crankshaft bearing cap and check oil clearance.

17. Check the crankshaft end play.



18. Lift the crankshaft (A) out of the engine, being careful not to damage journals.

NOTE: Arrange the main bearings and trust washers in the correct order.

19. Check fit between piston and piston pin. Try to move the piston back and forth on the piston pin. If any movement is felt, replace the pistonand pin as a set.

20. Remove piston rings.

1) Using a piston ring expender, remove the 2compressionrings.

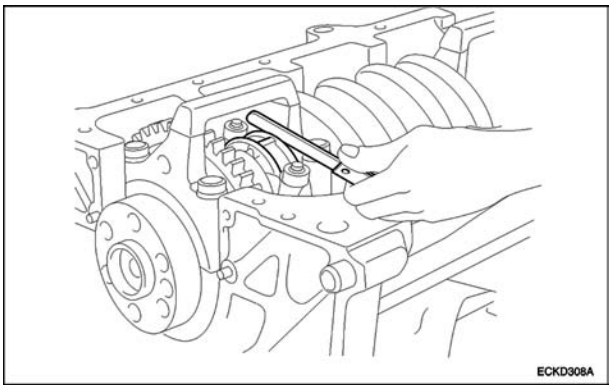
2) Remove the 2side rails and oil ring by hand.

NOTE: Arrange the piston rings in the correct order only.

21. Disconnect connecting rod from piston.

Inspection

Connecting Rod and Crankshaft

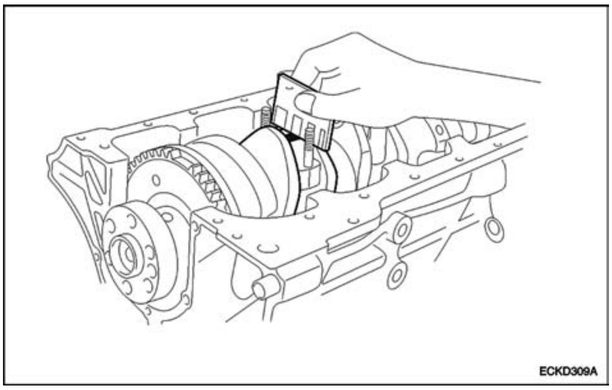


1. Check the connecting rod end play. Using feeler gauge, measure the end play while moving the connecting rod back and forth.

Standard end play:
0.1~0.25 mm (0.004~0.010in.)

Maximum end play: 0.4 mm (0.016in.)

- If out-of-tolerance, install a new connecting rod
- If still out-of-tolerance, replace the crankshaft.



2. Check the connecting road bearing oil clearance.

1) Check the matchmarks on the connecting rod and cap are aligned to ensure correct reassembly.

2) Remove the 2 connecting rod cap nuts.

3) Remove the connecting rod cap and bearing half.

4) Clean the crank pin and bearing.

5) Place plastigage across the crank pin.

6) Reinstall the bearing half and cap, and torque the nuts.

Tightening torque

50~53 Nm(500~530kgf.cm,36.9~39lbf.ft)

NOTE: Do not turn the crankshaft.

7) Remove the 2 nuts, connecting rod cap and bearinghalf.

8) Measure the plastigage at its widest point.

Standard oil clearance

0.024 ~ 0.042mm (0.0009 ~ 0.0017in.)

9) If the plastigage measures too wide or too narrow, remove the upper half of the bearing, install a new, complete bearing with the same color mark (select the color as shown in the next column), and recheck the clearance.

⚠ CAUTION

Do not file, shim, or scrape the bearings or the caps to adjust clearance.

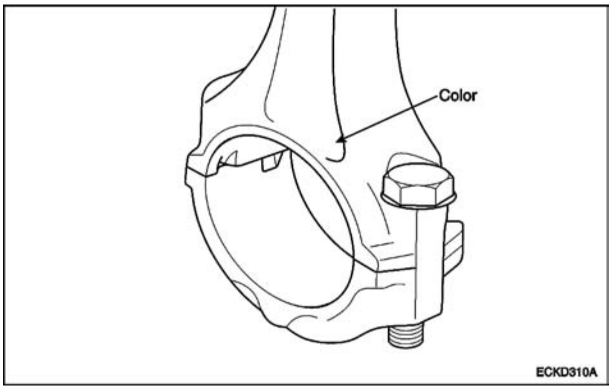
10) If the plastigage shows the clearance is still incorrect, try the next larger or smaller bearing (the color listed above or below that one), and check clearance again.

NOTE: If the proper clearance cannot be obtained by using the appropriate larger or smaller bearings, replace the crankshaft and start over.

⚠ CAUTION

If the marks are indecipherable because of an accumulation of dirt and dust, do not scrub them with a wire brush or scraper. Clean them only with solvent or deter gent.

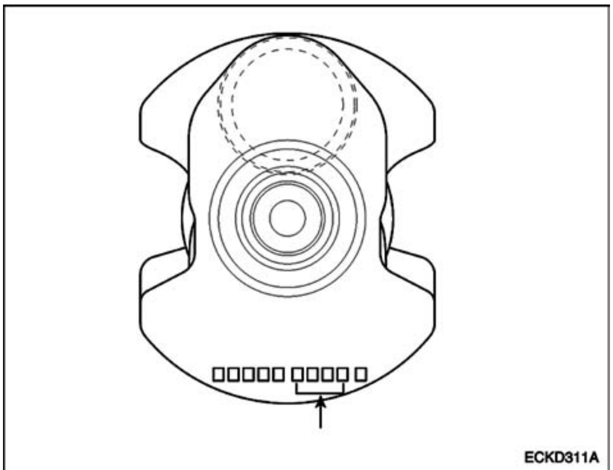
Connecting rod mark location

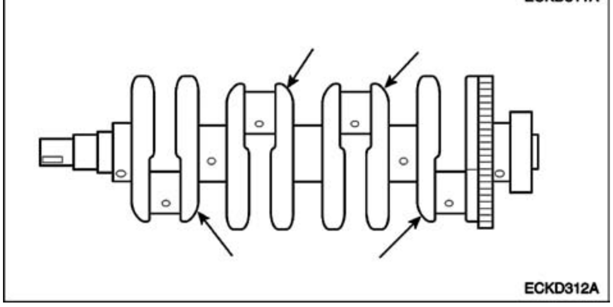


Discrimination of connecting rod

CLASS	MARK	INSIDEDIAMETER
a	WHITE	48.00~48.006mm (1.8896~1.8899in.)
b	NONE	48.006~48.012mm (1.8899~1.8902in.)
c	YELLOW	48.012~48.018mm (1.8902~1.8904in.)

Crankshaft pin mark location

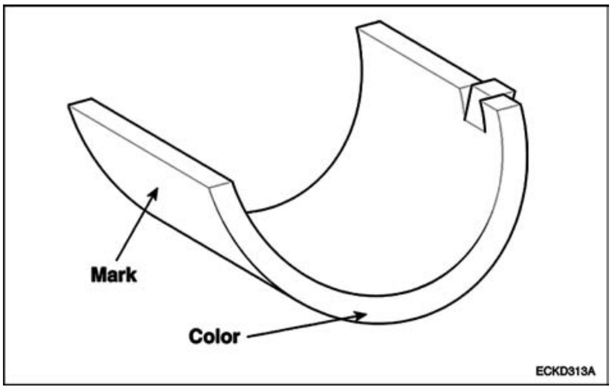




Discrimination of crankshaft

CLASS	MARK	OUTSIDE DIAMETER OF PIN
I	WHITE	44.960~44.966mm (1.7700~1.7703in.)
II	NONE	44.955~44.960mm (1.7698~1.7700in.)
III	YELLOW	44.948~44.955mm (1.7696~1.7698in.)

Place of identification mark (Connecting rod bearing)



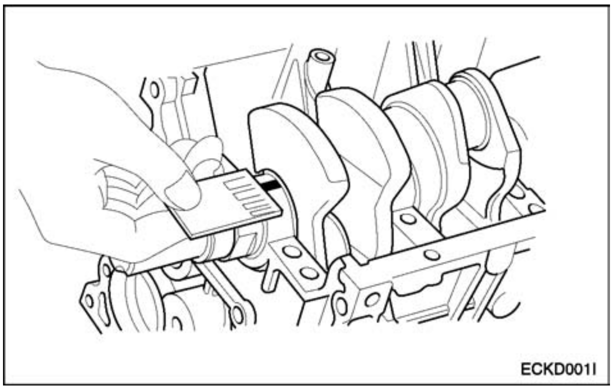
Discrimination of connecting rod bearing

CLASS	MARK	INSIDE DIAMETER
AA	BLUE	1.514~1.517 mm (0.0596~0.0597in.)
A	BLACK	A1.511~1.514 mm (0.0595~0.0596in.)
B	NONE	1.508~1.511 mm (0.0594~0.0595in.)
C	GREEN	1.505~1.508 mm (0.0593~0.0594in.)
D	YELLOW	1.502~1.505mm (0.0591~0.0593in)

11) Selection

CRANKSHAFT INDENTIFICATION MARK	CONNECTING ROD IDENTIFICATION MARK	ASSEMBLING CLASSIFICATION OF BEARING
I(YELLOW)	a (WHITE)	D(YELLOW)
	b (NONE)	C (GREEN)
	c (YELLOW)	B(NONE)
II(NONE)	a (WHITE)	C (GREEN)
	b (NONE)	B (NONE)
	c (YELLOW)	A (BLACK)
III(WHITE)	a (WHITE)	B (NONE)
	b (NONE)	A (BLACK)
	c (YELLOW)	AA (BLUE)

3. Check the crankshaft bearing oil clearance.



1) To check main bearing-to-journal oil clearance, remove the main caps and bearing halves.

2) Clean each main journal and bearing half with a clean shop tower.

3) Place one strip of plastic gage across each main journal.

4) Reinstall the bearings and caps, then torque the bolts.

Tightening torque : 30Nm (300kgf.cm, 22lbf.ft) + 60˚ ~ 65˚

NOTE: Do not turn the crankshaft.

5) Remove the cap and bearing again, and measure the widest part of the plastigage.

Standard oil clearance : 0.028 ~ 0.046 mm (0.0011 ~ 0.0018in.)

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6) If the plastigage measures too wide or too narrow, remove the upper half of the bearing, install a new, complete bearing with the same color mark (select the color as shown in the next column), and recheck the clearance.

⚠ CAUTION

Do not file, shim, or scrape the bearings or the caps to adjust clearance.

7) If the plastigage shows the clearance is still incorrect, try the next larger or smaller bearing (the color listed above or below that one), and check clearance again.

NOTE: If the proper clearance cannot be obtained by using the appropriate larger or smaller bearings, replace the crankshaft and start over.

⚠ CAUTION

If the marks are indecipherable because of an accumulation of dirt and dust, do not scrub them with a wire brush or scraper. Clean them only with solvent or detergent.

Connecting rods

1. When reinstalling, make sure that cylinder numbers put on the connecting rod and cap at disassembly match. When a new connecting rod i s installed, make sure that the notches for holding the bearing in place are on the same side.

2. Replace the connecting rod if it is damaged on the thrust faces at either end. Also if step wear or a severely rough surface of the inside diameter of the small end is apparent, the rod must be replaced aswell.

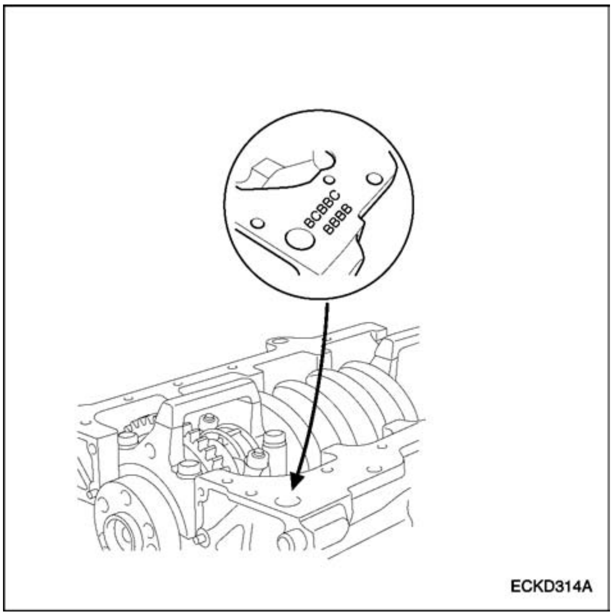
3. Using a connecting rod aligning tool, check the rod for bend and twist. If the measured value is close to the repair limit, correct the rod by a press. Any connecting rod that has been severely bent or distorted should be replaced.

Allowable bend of connecting rod : 0.05mm / 100 mm (0.0020in./3.94in.) or less
Allowable twist of connecting rod : 0.1mm / 100mm (0.0039in./3.94in.) or less

Crankshaft bore mark location

Letters have been stamped on the end of the block as a mark for the size of each of the 5 main journal bores.

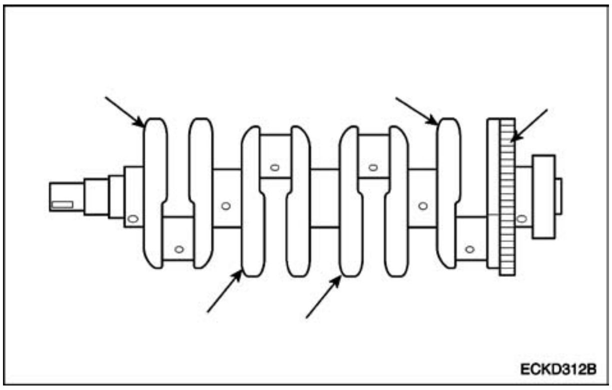
Use them, and the numbers or bar stamped on the crank (marks for main journal size), to choose the correct bearings.



Discrimination of cylinder block

CLASS	MARK	INSIDE DIAMETER
a	A	59.000~59.006mm (2.3228~2.3230in.)
b	B	59.006~59.012mm (2.3230~2.3233in.)
c	C	59.012~59.018mm (2.3233~2.3235in.)

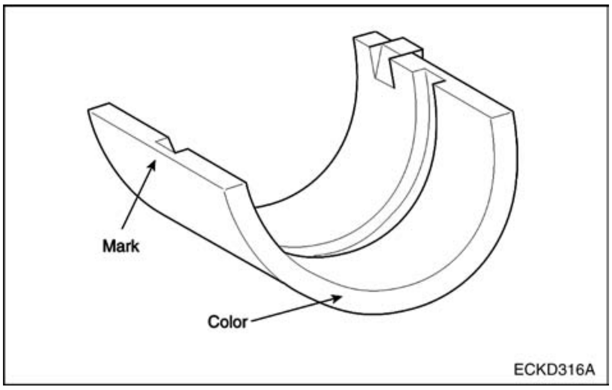
Crankshaft journal mark location



Discrimination of crankshaft

CLASS	MARK	OUTSIDE DIAMETER OF JOURNAL
I	YELLOW	54.956~54.962mm (2.1636~2.1638in.)
II	NONE	54.950~54.956mm (2.1633~2.1636in.)
III	WHITE	54.944~54.950mm (2.1631~2.1633in.)

Place of identification mark (Crankshaft bearing)



Discrimination of crankshaft bearing

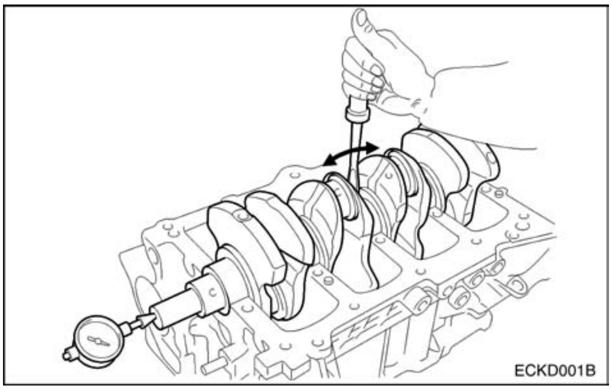
CLASS	MARK	THICKNESS OF BEARING
AA	BLUE	2.014~2.017mm (0.0793~0.0794in.)
A	BLACK	2.011~2.014mm (0.0791~0.0793in.)
B	NONE	2.008~2.011mm (0.0790~0.0791in.)
C	GREEN	2.005~2.008mm (0.0789~0.0790in.)
D	YELLOW	2.002~5.005mm (0.0788~0.0789in.)

Selection

CRANKSHAFT INDENTIFICATION MARK	CRANK-SHAFT BORE IDENTIFICATION MARK	ASSEM-BLING CLASSIFICATION OF BEARING
I(YELLOW)	a (A)	D(YELLOW)
	b (B)	C (GREEN)
	c (C)	B(NONE)
II(NONE)	a (A)	C (GREEN)
	b (B)	B (NONE)
	c (C)	A (BLACK)
III(WHITE)	a (A)	B (NONE)
	b (B)	A (BLACK)
	c (C)	AA (BLUE)

4. Check crankshaft endplay. Using a dial indicator, measure the thrust clearance while prying the crankshaft back and forth with a screwdriver.

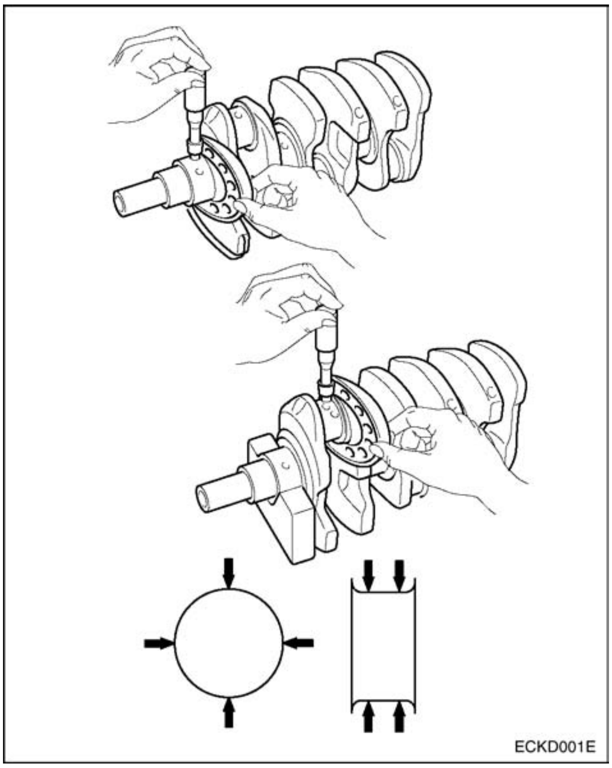
Standard end play : 0.06 ~ 0.26mm (0.0023 ~ 0.010in.)
Limit : 0.30 mm (0.0118in.)



If the end play is greater than maximum, replace the thrust bearings as a set.

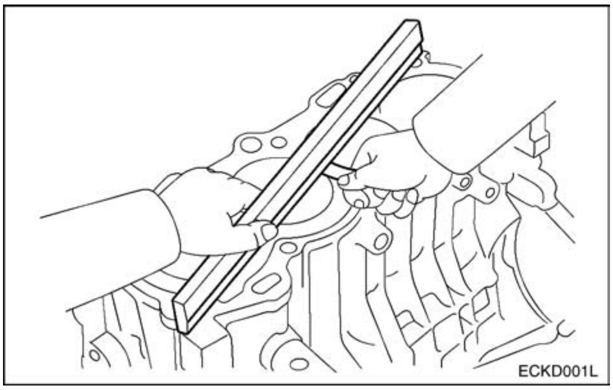
Thrust bearing thickness : 2.44 ~ 2.47 mm(0.096 ~ 0.097in.)

5. Inspect main journals and crank pins Using a micrometer, measure the diameter of each main journal and crankpin.



Main journal diameter : 55 mm (2.165in.)
Crank pin diameter : 45 mm (1.77in.)

Cylinder Block

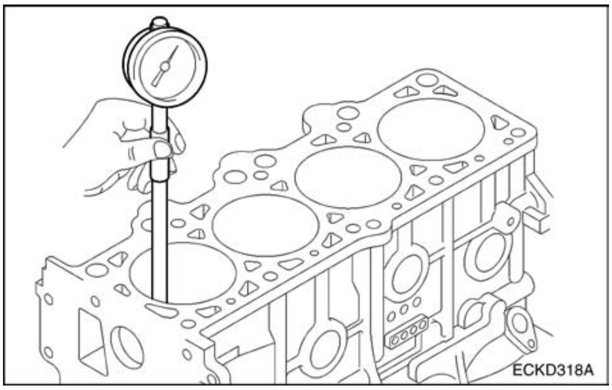


1. Remove gasket material. Using a gasket scraper, remove all the gasket material from the top surface of the cylinder block.

2. Clean cylinder block Using a soft brush and solvent, thoroughly clean the cylinder block.

3. Inspect top surface of cylinder block for flatness. Using a precision straight edge and feeler gauge, measure the surface contacting the cylinder head gasket for warpage.

Flatness of cylinder block gasket surface
Standard : Less than 0.03 mm (0.0012in.)
Limit : 0.05 mm (0.0020in.)



4. Inspect cylinder bore diameter Visually check the cylinder for vertical scratchs. If deep scratches are present, replace the cylinder block.

5. Inspect cylinder bore diameter Using a cylinder bore gauge, measure the cylinder bore diameter at position in the thrust and axial directions.

Standard diameter: 82.00 ~ 82.03 mm (3.2283 ~ 3.2295in.)

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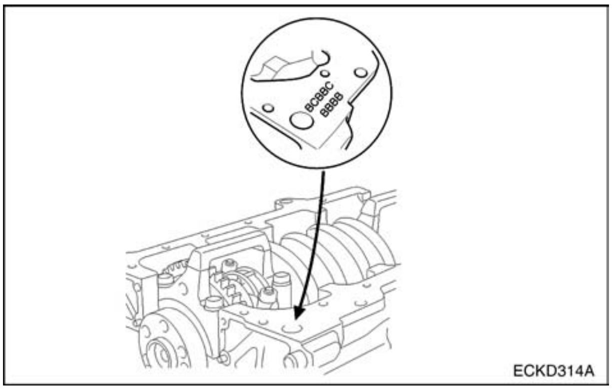
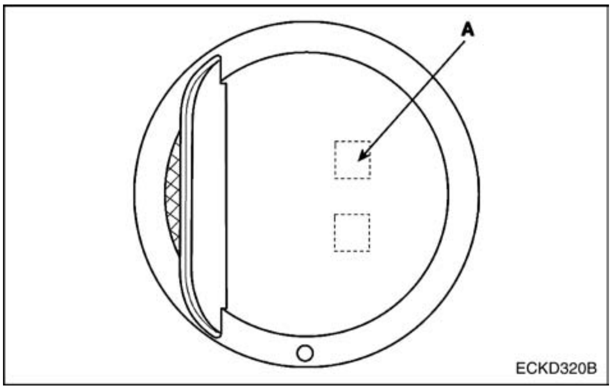
6. Check the cylinder bore size code on the cylinder block bottom face.



Class	Cylinder bore inner diameter	Size code
A	82.00~82.01mm (3.2283~3.2287in.)	A
B	82.01~82.02mm (3.2287~3.2291in.)	B
C	82.02~82.03mm (3.2291~3.2295in.)	C

7. Check the piston size code (A) on the piston top face



NOTE: Stamp the grade mark of basic diameter with rubber stamp

Class	Piston outer diameter	Size code
A	81.97~81.98mm (3.2271~3.2275in.)	A
B	81.98~81.99mm (3.2275~3.2279in.)	None
C	81.99~82.00mm (3.2279~3.2283in.	C

8. Select the piston related to cylinder bore class.

Clearance
0.02 ~ 0.04 mm (0.00078 ~ 0.00157in.)
Boring cylinder

1. Oversize pistons should be selected according to the largest bore cylinder.

Identification Mark	Size
0.25	0.25 mm (0.010in.)
0.50	0.50 mm (0.020in.)

NOTE: The size of piston is stamped on top of the piston.

2. Measure the outside diameter of the piston to be used.

3. According to the measured O.D., calculate the new bore size.

New bore size = Piston O.D + 0.02 to 0.04 mm (0.0008 to 0.0016 in.) (clearance between piston and cylinder) -0.01 mm (0.0004in.) (honing margin.)

4. Bore each of the cylinders to the calculated size.

⚠ CAUTION

To prevent distortion that may result from temperature rise during honing, bore the cylinder holes in the firing order.

5. Hone the cylinders, finishing them to the proper dimension (piston outside diameter + gap with cylinder).

6. Check the clearance between the piston and cylinder.

Standard: 0.02-0.04 mm (0.0008-0.0016 in.)

NOTE: When Boring The cylinders, finish all of the cylinders to the same oversize. Do not bore only one cylinder to the oversize.

Piston and Rings

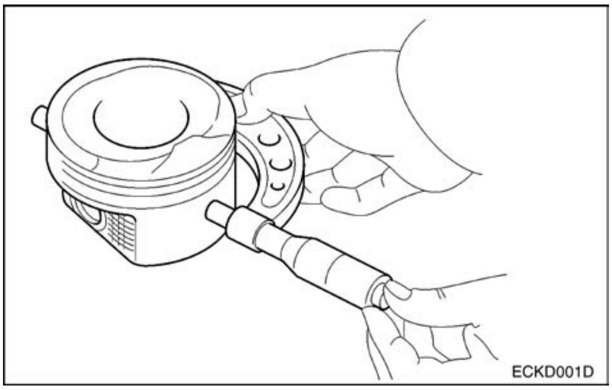
1. Clean piston

1) Using a gasket scraper, remove the carbon from the piston top.

2) Using a groove cleaning tool or broken ring, clean the piston ring grooves.

3) Using solvent and a brush, thoroughly clean the piston.

NOTE: Do not use a wire brush.

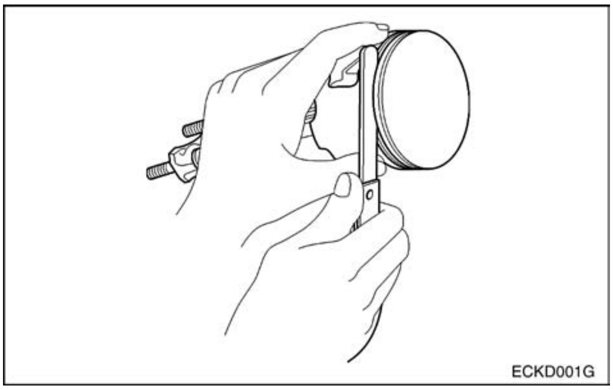


2. The standard measurement of the piston outside diameter is taken 47 mm (1.85in.) from the top land of the piston.

Standard diameter
81.97 ~ 82.00 mm(3.2272 ~ 3.2283in.)

3. Calculate the difference between the cylinder bore diameter and the piston diameter.

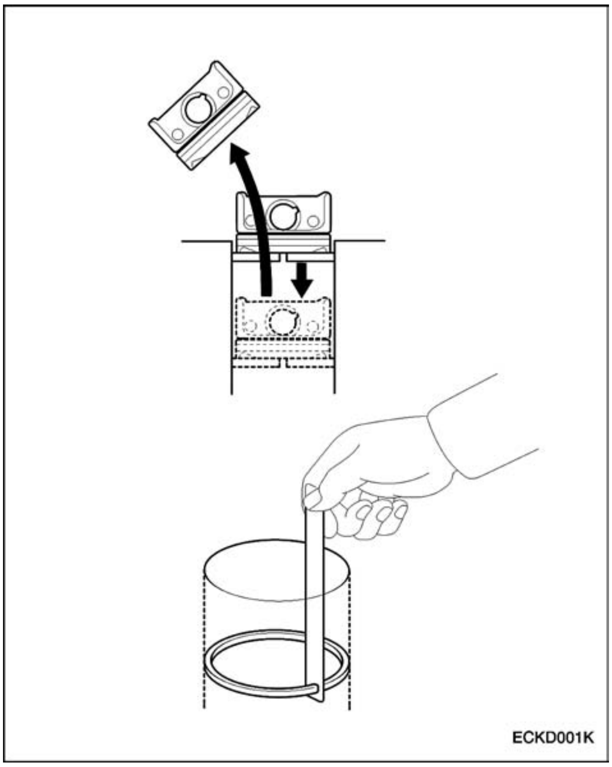
Piston-to-cylinder clearance
0.02 ~ 0.04 mm (0.0008 ~ 0.0016 in.)



4. Inspect the piston ring side clearance. Using a feeler gauge, measure the clearance between new piston ring and the wall of the ring groove.

Piston ring side clearance
No.1: 0.04 ~ 0.08 mm (0.0016 ~ 0.0031in.)
No.2: 0.03 ~ 0.07 mm (0.0012 ~ 0.0028in.)
Limit
No.1: 0.1 mm (0.004in.)
No.2: 0.1 mm (0.004in.)

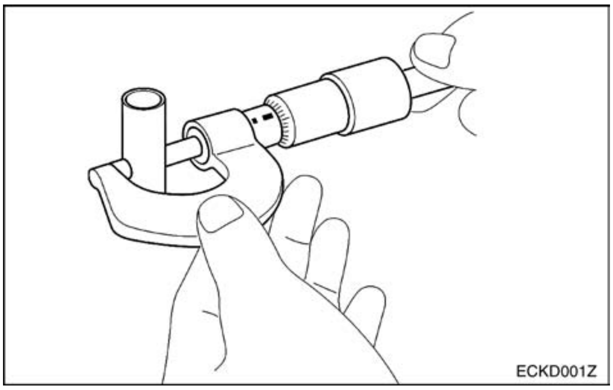
If the clearance is greater than maximum, replace the piston.



5. Inspect piston ring end gap. To measure the piston ring end gap, insert a piston ring into the cylinder bore. Position the ring at right angles to the cylinder wall by gently pressing it down with a piston. Measure the gap with a feeler gauge. If the gap exceeds the service limit, replace the piston ring. If the gap is too large, recheck the cylinder bore diameter against the wear limits, If the bore is over the service limit, the cylinder block must be rebored.

Piston ring end gap
Standard
No.1: 0.23~0.38 mm (0.0091~0.0150in.)
No.2: 0.33~0.48 mm (0.0130~0.0189in.) [2.0L]
Limit
No.1,2,oil ring:1.0mm(0.039in.)

Piston Pins



1. Measure the diameter of the piston pin.

Piston pin diameter
20.001~20.006 mm (0.7874 ~ 0.7876in.)

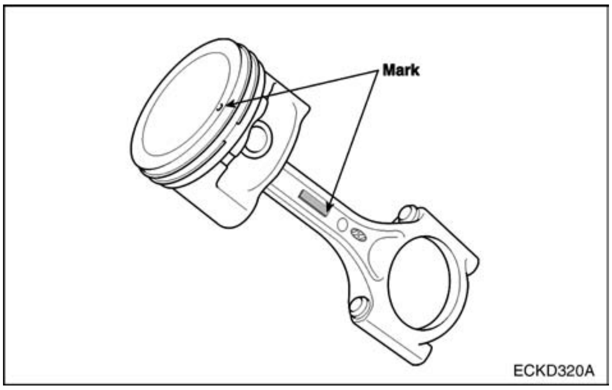
2. Measure the piston pin-to-piston clearance.

Piston pin-to-piston clearance
0.01 ~ 0.02 mm (0.0004 ~ 0.0008in.)

3. Check the difference between the piston pin diameter and the connecting rod small end diameter.

Piston pin-to-connecting rod interference
0.016 ~ 0.032 mm (0.00063 ~ 0.00126in.)

Reassembly

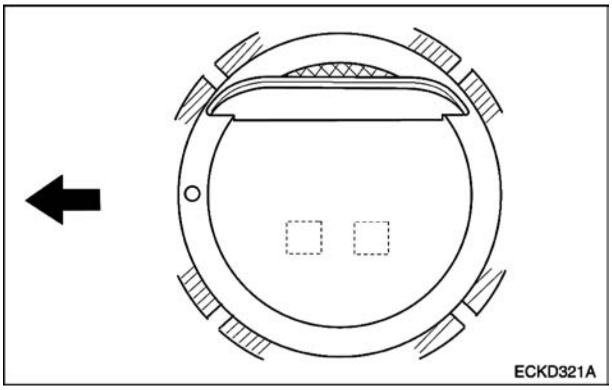


NOTE: Thoroughly clean all parts to assembled. Before installing the parts, apply fresh engine oil to all sliding and rotating surfaces. Replace all gaskets, O-rings and oil seals with new parts.

1. Assemble piston and connecting rod.

1) Use a hydraulic press for installation.

2) The piston front mark and the connecting rod front mark must face the timing belt side of the engine.

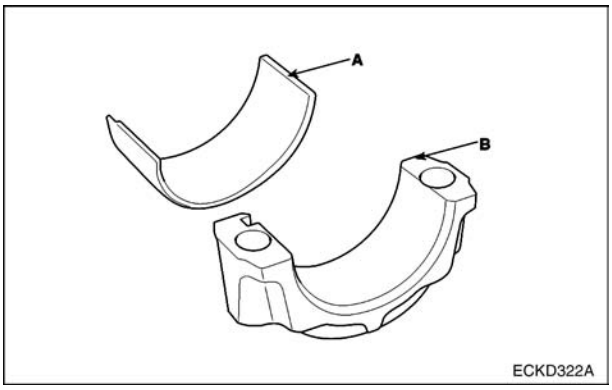


2. Install piston rings.

1) Install the oil ring expander and 2 side rails by hand.

2) Using a piston ring expander, install the 2compression rings with the code mark facing upward.

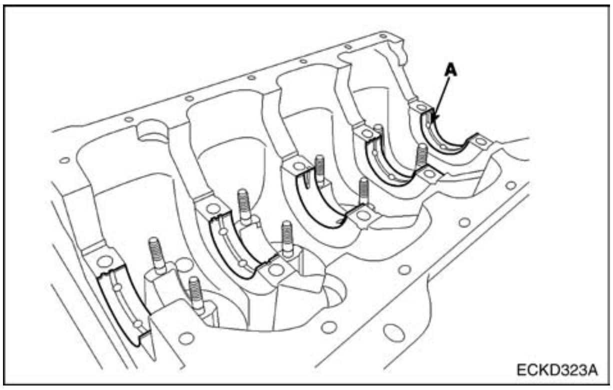
3) Position the piston rings so that the ring ends are as shown.



3. Install connecting rod bearings.

1) Align the bearing claw with the groove of the connecting rod cap.-

2) Install the bearings (A) in the connecting rod and connecting rod cap (B).

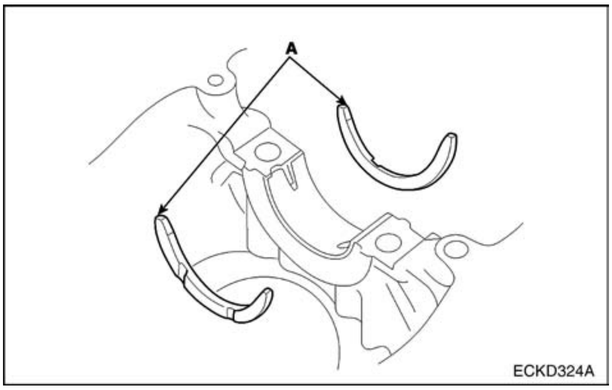


4. Install main bearings.

NOTE: Upper1,2,4,5 bearings have an oil groove of oil holes; Lower bearings do not.

1) Align the bearing claw with the claw groove of the cylinder block, push in the 5 upper bearings (A).

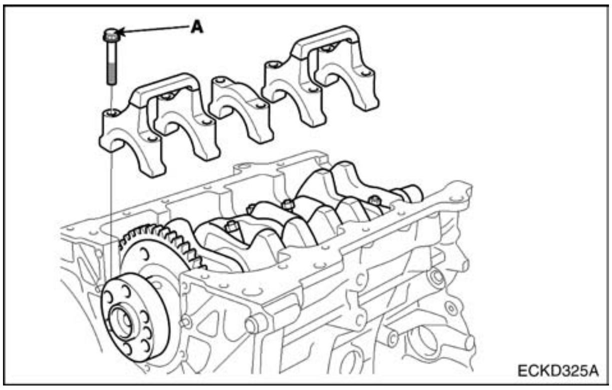
2) Align the bearing claw with the claw groove of the main bearing cap, and push in the 5 lower bearings.



5. Install thrust bearings.
Install the 2 thrust bearings (A) under the No.3journal position of the cylinder block with the oil grooves facing outward.

6. Place crankshaft on the cylinder block.

7. Place main bearing caps on cylinder block.



8. Install main bearing cap bolts.

NOTE: The main bearing cap bolts are tightened in 2 progressive steps. If any of the bearing cap bolts in broken or deformed, replace it.

1) Apply a light coat of engine oil on the threads and under the bearing cap bolts.

2) Install and uniformly tighten the 10 bearing cap bolts (A), in several passes, in the sequence shown.

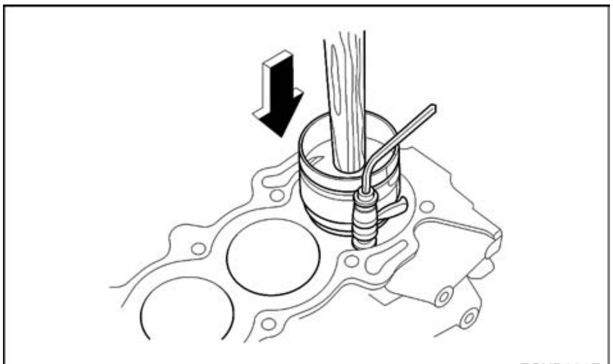
Tightening torque
30Nm (300kgf.cm, 22lbf.ft)

3) Retighten the bearing cap bolts by 6065 in the numerical order shown.

Tightening torque
Main bearing cap bolt:
30Nm (300kgf.cm,22lbf.ft)+60˚~65˚

4) Check that the crankshaft turns smoothly.

9. Check crankshaft end play.


ECKD001F

10. Install piston and connecting rod assemblies.

NOTE: Before installing the pistons, apply a coat of engine oil to the ring grooves and cylinder bores.

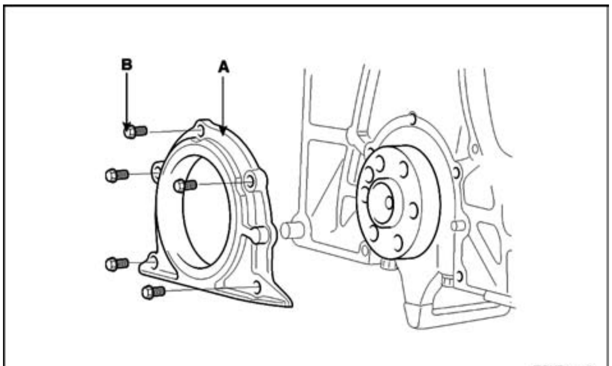
1) Remove the connecting rod caps, and slip short sections of rubber hose over the threaded ends of the connecting rod bolts.

2) Install the ring compressor, check that the bearing is securely in place, then position the piston in the cylinder, and tap it in using the wooden handle of a hammer.

3) Stop after the ring compressor pops free, and check the connecting rod-to-check journal alignment before pushing the piston into place.

4) Apply engine oil to the bolt threads. Install the rod caps with bearings, and torquethenuts: 50~53Nm(500~530kgf.cm,36.9~39lbf.ft)

NOTE: Maintain downward force on The ring compressor to prevent the rings from expanding before entering the cylinder bore.

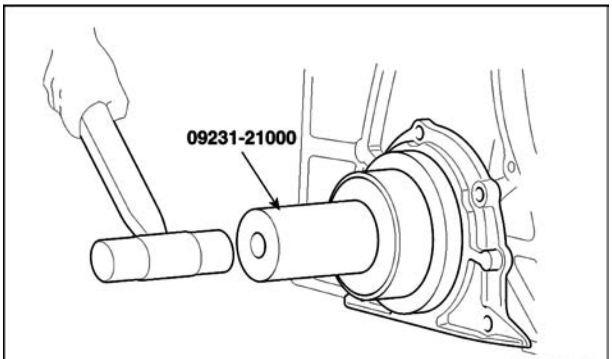


ECKD306A

11. Install a new gasket and rear oil seal case (A) with 5 bolts (B).

Tightening torque
10~12Nm (100~120kgf.cm, 7.3~8.8lbf.ft)

NOTE: Check that the mating surfaces are clean and dry.



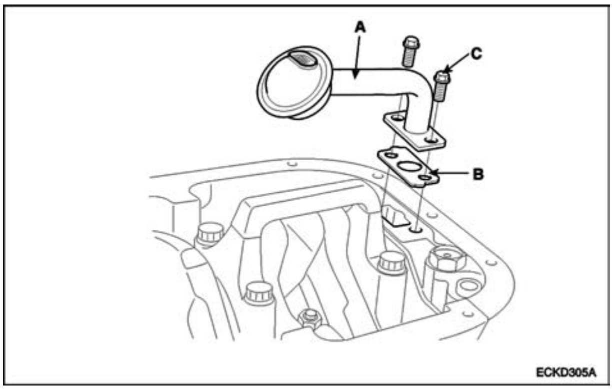
ECKD326A

12. Install rear oil seal.

1) Apply engine oil to a new oil seal lip.

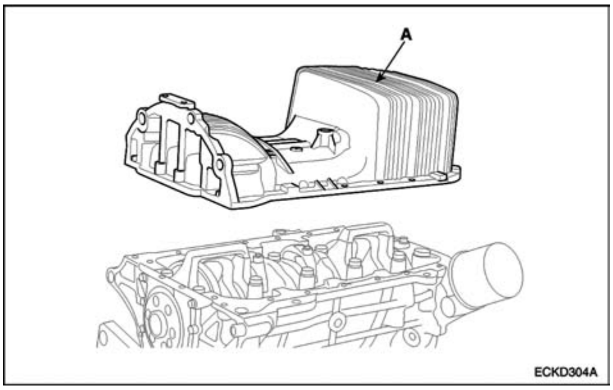
2) Using SST (09231-21000) and a hammer, tap in the oil seal until its surface is flush with the rear oil seal retainer edge.

13. Install front case.



14. Install oil screen.
Install a new gasket (B) and oil screen (A) with 2 bolts (C).

Tightening torque
12~15Nm (120~150kgf.cm,9~11lbf.ft)



15. Install oil pan.

1) Using a razor blade and gasket scraper, remove all the old packing material from the gasket surfaces.

NOTE: Check that the mating surfaces are clean and dry before applying liquid gasket.

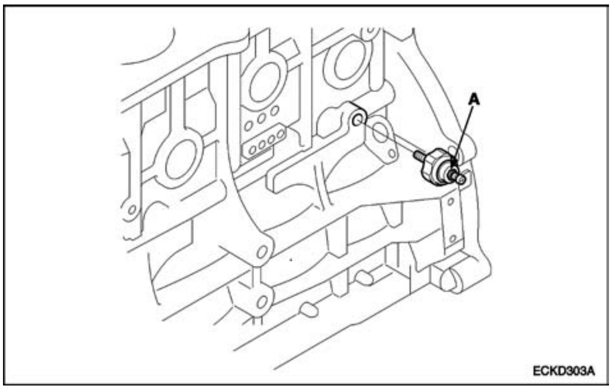
2) Apply liquid gasket as an even bead, centered between the edges of the mating surface. Use liquid gasket MS721-40A or equivalent.

NOTE: To prevent leakage of oil, apply liquid gasket to the inner threads of the bolt holes. Do not install the parts if five minutes or more have elapsed since applying the liquid gasket. Instead, reapply liquid gasket after removing the residue. After assembly, wait at least 30 minutes before filling the engine with oil.

3) Install the oil pan (A) with the 19 bolts.
Uniformly tighten the bolts in several passes.

Tightening torque
10~12Nm (100~120kgf.cm, 7.3~8.8lbf.ft)

16. Install water pump. (see page EM-104)

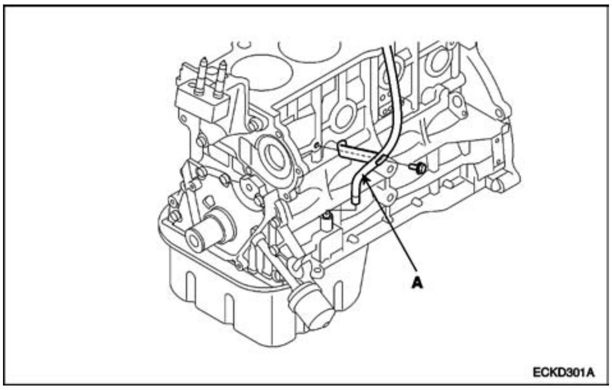


17. Install oil pressure sensor.

1) Apply adhesive to 2 or 3 threads.
Adhesive: MS721-39 (B) or equivalent.

2) Install the oil pressure sensor (A).

Tightening torque
15~22Nm (150~220kgf.cm, 11~16lbf.ft)



18. Install oil level gauge assembly.

1) Install a new O-ring on the oil level gauge.

2) Apply engine oil on the O-ring.

3) Install the oil level gauge assembly (A) with the bolt.

Tightening torque
12~15Nm (120~150kgf.cm, 9~11lbf.ft)
19. Install cylinder head.

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19. Install timing belt.

20. Remove engine stand.

21. Install flywheel housing.

22. Install flywheel.

Tightening torque
120~130Nm (1200~1300kgf.cm,89~96lbf.ft)

Chapter 4. ENGINE ELECTRICAL SYSTEM

Specifications

Ignition Coil

Item	Specification
1st coil resistance	0.71±10%(Ω)
2nd coil resistance	18~19.5±15%(kΩ)

Spark Plug

Item		Specification
Type	NGK	PFR6N
	CHAMPION	RC8PYPB
Spark plug gap		0.7 ~ 0.8mm

Starter Motor

Item	Specification
Output	12V- 1.7 kW
Pinion tooth number	8

Alternator

Item	Specification
Rated output	13.5V - 90A
RPM	1,000 ~ 18,000rpm
Voltage regulator type	Electronic, Built-in type

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Ignition coil drivers *
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Cam position sensor *
  (for sequential ignition or fuel injection only)
- Cam timing wheel *
  (for sequential ignition or fuel injection only)
- Spark plugs *

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

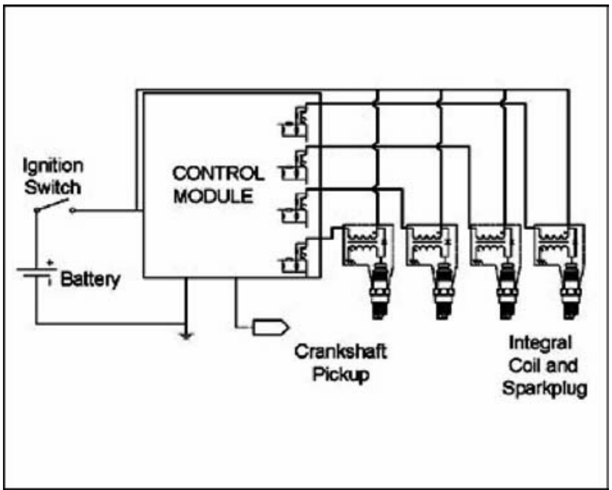


Figure 16. Coil-On-Plug Ignition System

Coil-On-Plug Ignition System

Coil-on-plug (COP) is a type of distributorless ignition system where individual ignition coils are mounted directly over each spark plug. No spark plug wires are used. On most engines, the plugs and coils are located on top of the cylinder head for easy mounting of the coils. A topside location is best because it keeps the coils away from the heat of the exhaust.

COP Components

In a typical COP ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to determine firing order and turn the individual ignition coils on and off.

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

The primary difference between COP and other ignition systems is that each COP coil is mounted directly atop the spark plug so the voltage goes directly to the plug electrodes without having to pass through a distributor or wires. It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).

Misfires

COP problems can include many of the same ailments as other ignition systems such as misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM can kill an individual coil and prevent that cylinder from firing. But with COP, an individual coil failure will only cause misfiring in one cylinder.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, even contaminated fuel. These other possibilities should all be ruled out before a COP unit is replaced.

A COP engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

Figure 17. Ignition Coil and Extension Wire Assembly for G420F(E) Engiue

COP Checks

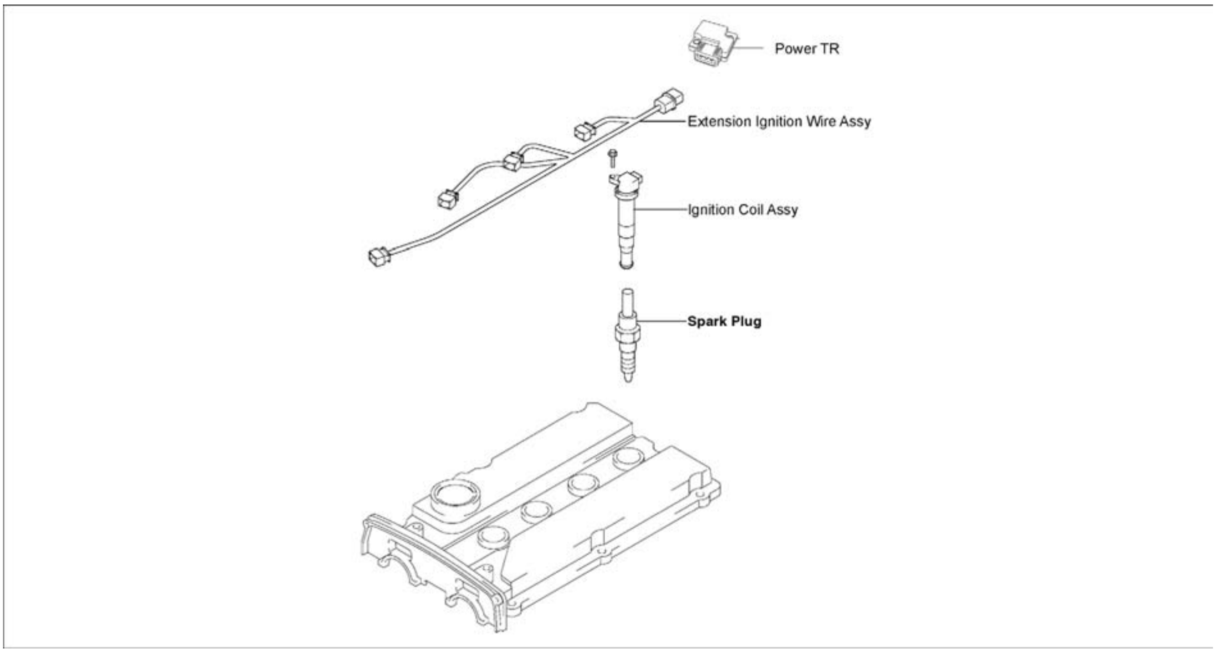
Individual ignition coils can be tested with an ohmmeter the same as those on a conventional distributor or DIS ignition system. Measure primary and secondary resistance and compare to specifications. If resistance is out of specifications, the coil is bad and needs to be replaced.

Also, pay close attention to the tube that wraps around the spark pug. Cracks can allow voltage to jump to ground causing a misfire. The spark plug terminal should also fit tightly.

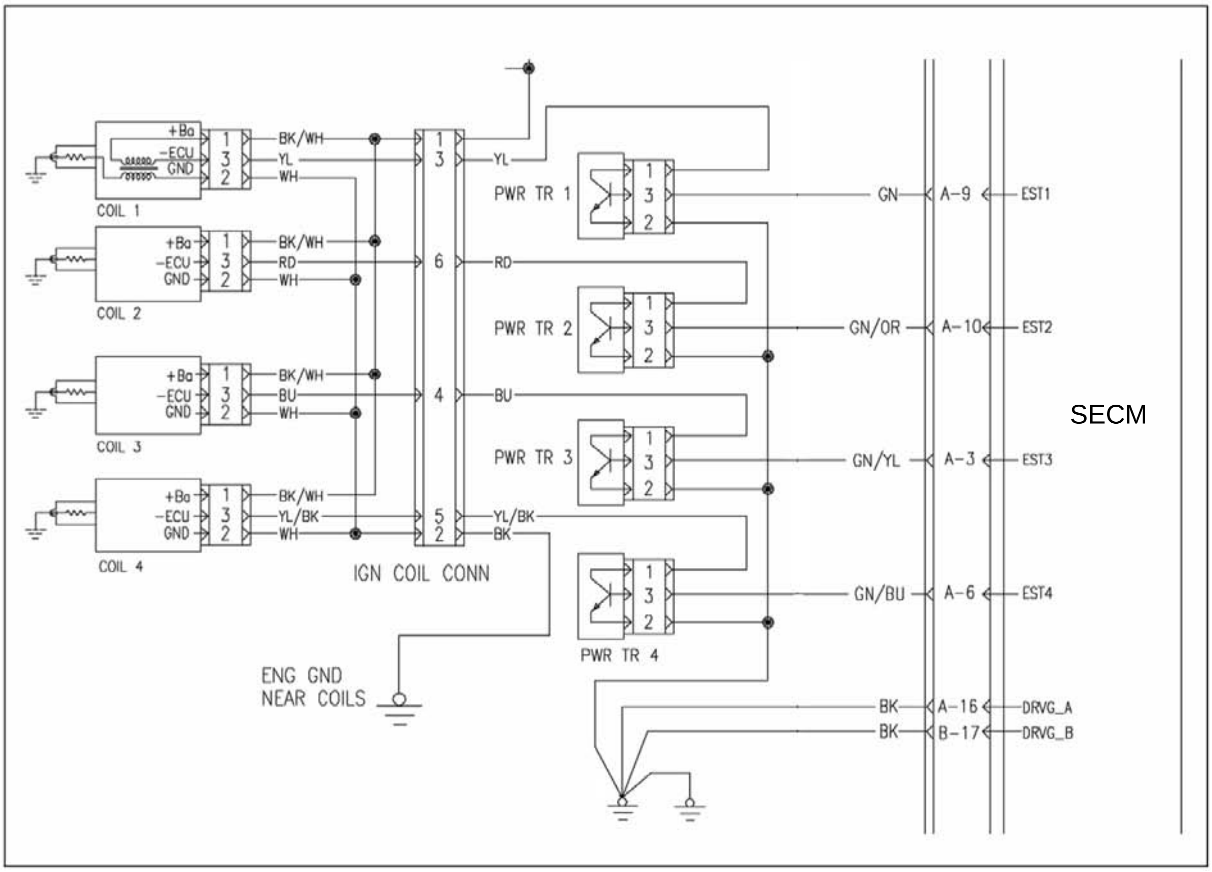
If a COP coil tests bad and is replaced, cleaning the COP connector and wiring harness terminals can often avoid future problems. Corrosion at either place can cause intermittent operation and loss of continuity, which may contribute to component failure. Applying dielectric grease to these connections can help prevent corrosion and assure a good electrical connection.

Magnetic crankshaft position sensors can be tested with an ohmmeter, and the sensor output voltage and waveform can be read with an oscilloscope. The output voltage of a Hall Effect crankshaft position sensor can be checked with a voltmeter. On most vehicles, a defective crank position sensor will usually set a fault code that can be read with the Service Tool.

Components



Circuit Diagram



Inspection of Ignition Timing

1. Inspection condition

Coolant temperature : 80-90°C
(At normal temperature)

Lamp and all accessories : OFF
Transmission : In neutral position
Parking brake : ON

2. Inspection

1) Connect the timing light.

2) After inserting the clip backward the connector, connect the tachometer with the special tool (09273-24000)

⚠ CAUTION

Take care not to disconnect the connector.

3) Measure RPM.

RPM

Low Idle	750 ± 15 rpm

NOTE: If RPM is not normal, it is impossible to measure the proper ignition timing, so measure it at a normal RPM.

4) Inspect the standard ignition timing.

BTDC	5˚ ± 5˚

5) If ignition timing is out of the standard, inspect sensors concerned with ignition timing.

⚠ CAUTION

Because ignition timing is fixed by set data value in ECU, it is impossible to control on purpose.
Fisrt, check that sensors send output properly to help determine ignition timing control.

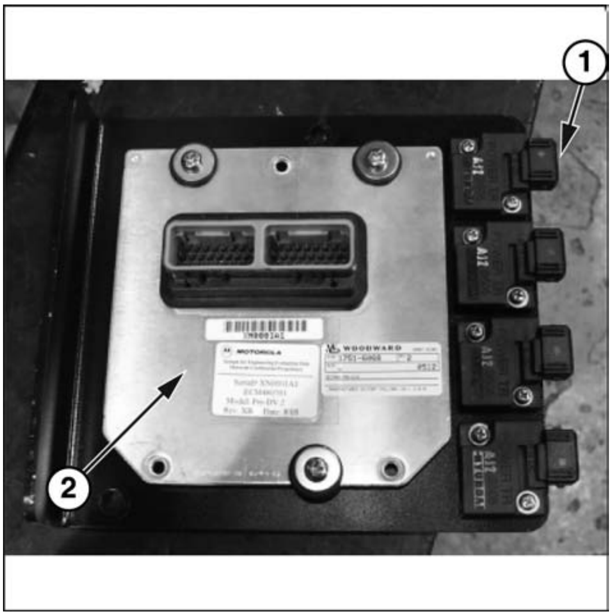
NOTE: Affective ECU input to Ignition timing control
Coolant temperature sensor
Oxygen sensor
MAP sensor(Engine load)
Crankshaft position sensor
Throttle position sensor
Intake Air Temperature sensor

6) Check that actual ignition timing is changed with engine RPM increased.

Inspection of Ignition Coil Drivers (Power TR)

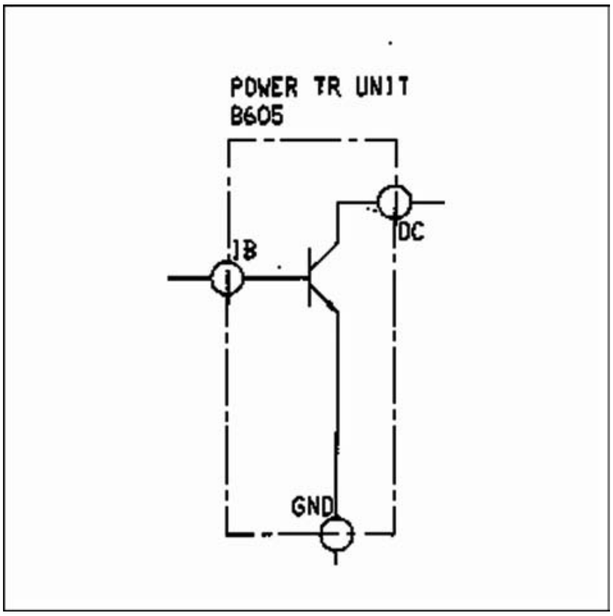
Four Power Transistors are used for G420F(E) engine. Its function is ignition coil driver, and it is located near to SECM.

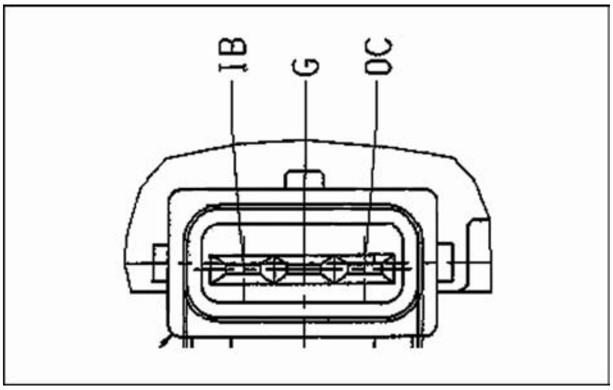
Location of Components



(1) Power TRs (2) SECM

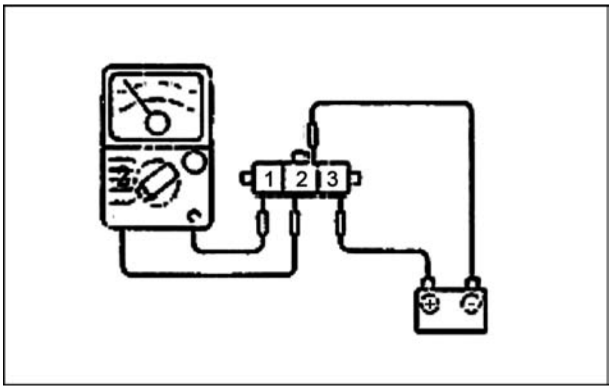
Circuit Diagram





IB (Terminal #3), OC (Terminal #1), GND (Terminal #2)

Inspection



1. Connect terminal #2 (Ground) of Power TR to Battery (-).

2. Connect terminal #3(IB) of Power TR to Battery (+5V). If the resistance between terminal #2 and terminal #1(OC) is lower than 10 ohms, it is OK.

3. Disconnect terminal #3(IB) of Power TR to Battery (+5V). If the resistance between terminal #2 and terminal #1(OC) is infinite, it is OK.

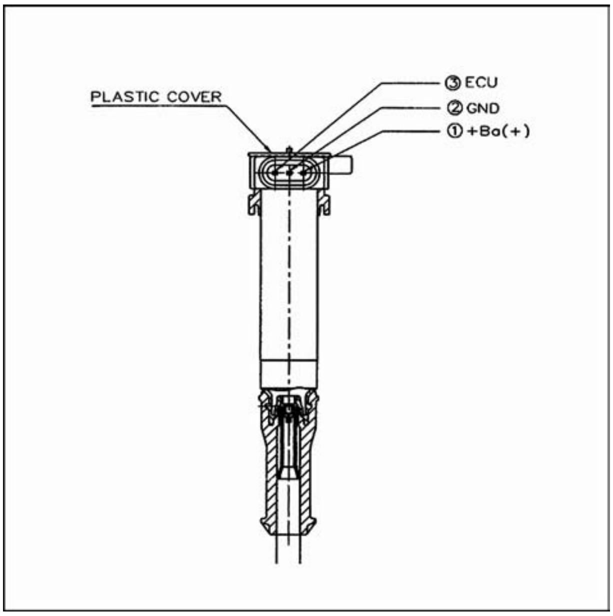
Inspection of Ignition Coil

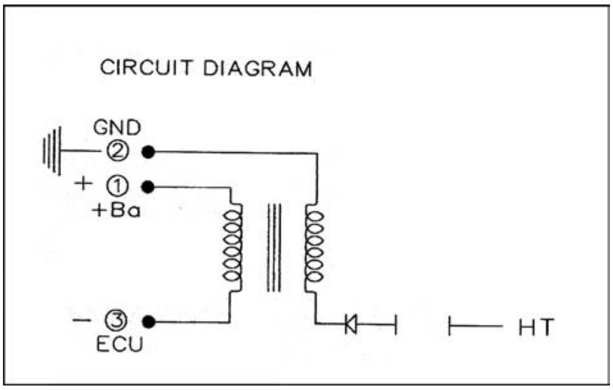
Description

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

The primary difference between COP and other ignition systems is that each COP coil is mounted directly atop the spark plug so the voltage goes directly to the plug electrodes without having to pass through a distributor or wires. It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).

Component and Circuit Diagram





Inspection

1. 1st Coil Resistance Measurement
Measure resistance between no.1 (Ba+) and no.3 (ECU) terminals of ignition coil.

1st Coil Resistance : 0.71 ± 9 % (Ω)

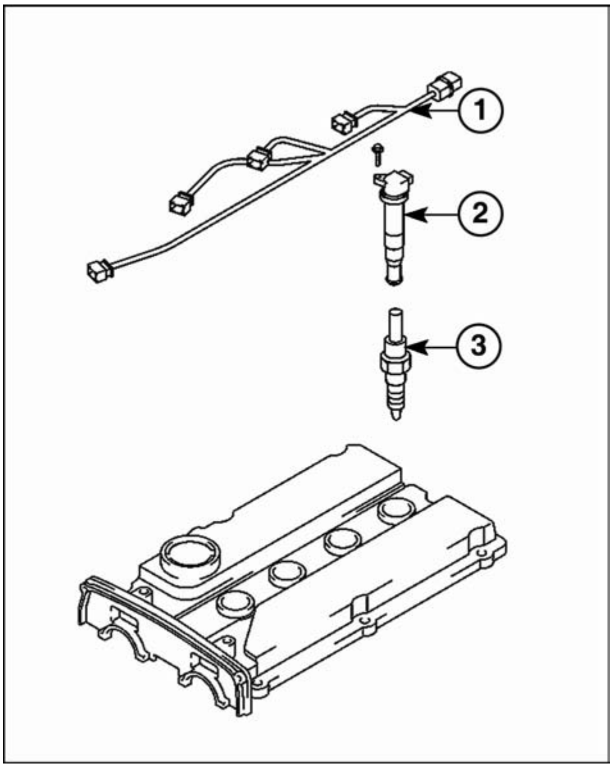
---

2. 2nd Coil Resistance measurement
Measure resistance between high pressure terminals.

2nd Coil Resistance : 18～19.5 ± 14 % (kΩ)

Inspection of Spark Plug

Inspection and clean



① Ignition wire Ass'y ② Ignition Coil Ass'y
③ Spark Plug

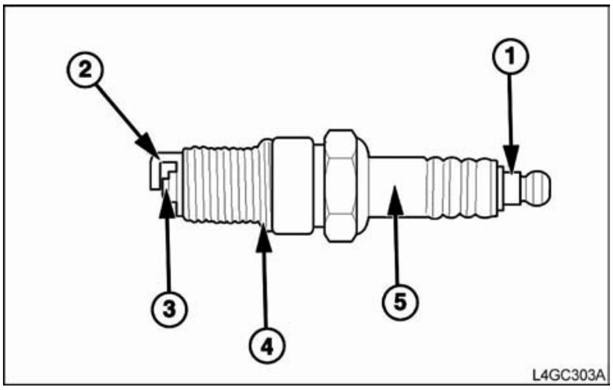
1. Disconnect the ignition wire ass'y from the ignition coil ass'y.

2. Remove the ignition coil ass'y by pulling the ignition coil with hand.

3. Remove all spark plugs from the cylinder head using a spark plug wrench.

⚠ CAUTION

Take care not to come foreign materials into spark-plug mounting hole.



3. Check the spark plug as below.

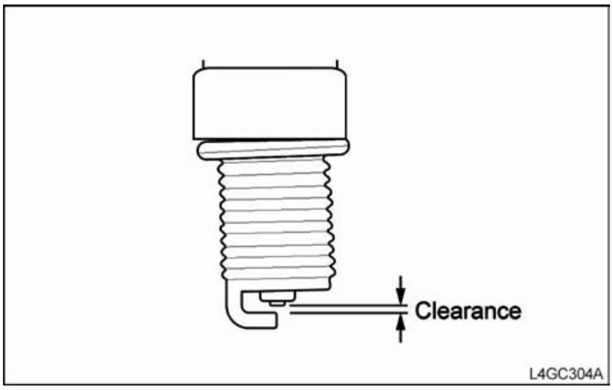
1) Insulator broken

2) Terminal worn

3) Carbon deposit

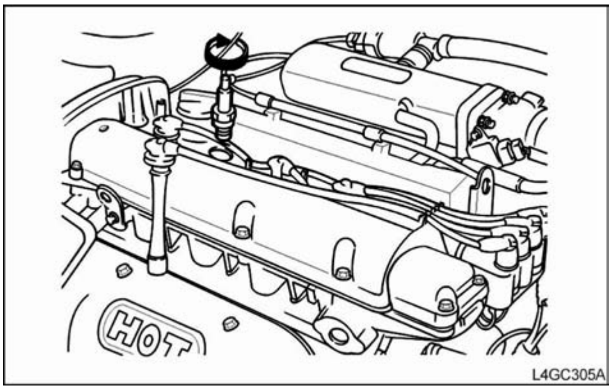
4) Gasket damaged or broken

5) Porcelain insulator of spark plug clearance



4. Check the plug clearance using a plug clearance gauge and if the value is not within the specified values, adjust it by bending the ground clearance. When installing a new sparkplug, install it after checking the uniform plug clearance.

Spark plug clearance	0.7~0.8mm



5. Install the spark plug and tighten it to the specified torque.
Take care not to over tighten it to prevent cylinder head threads from damage.

Tightening torque	2~3kg·m

Spark Plug Analysis

State	Contact point is black	Contact point is white
Description	• Density of the fuel mixture is thick • Lack of air intake	• Density of the fuel mixture is thin • Ignition timing is fast • Spark plug is tight • Lack of torque

Charging System

General Description

The alternator is an electrical and mechanical components driven by a belt from engine rotation. It is used to charge the storage battery during the engine operation. The alternator is cooled by an external fan mounted behind the pulley. The fan pulls air through the holes in the back of the alternator. The air exits the front of the alternator, cooling it in the process. The valeo alternator also has an internal fan. This fan is mounted on the rotor. This fan pulls air through the holes in the back of the alternator to cool the rectifier bridge and regulator. The air exits the front of the alternator.

The alternator converts mechanical and magnetic energy to alternating current (AC) and voltage. This process is done by rotating a direct current (DC)electromagnetic field (rotor) inside a three phase stator. The alternating current and voltage (generated by the stator) are changed to direct current by a three phase, full wave rectifier system using six silicone rectifier diodes. Some alternators have three exciter diodes or a diode trio. They rectify the current needed to start the charging process. Direct current flows to the alternator output terminal.

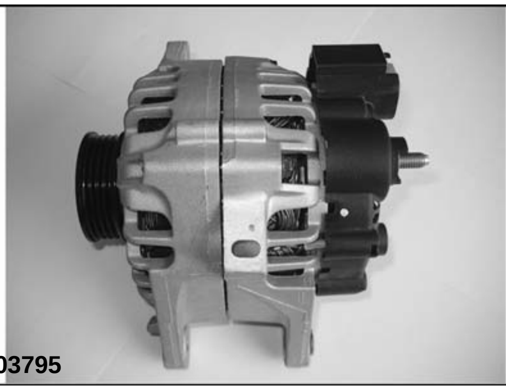
A solid state regulator is installed in or on the back of the alternator. Two brushes conduct current, through two slip rings, to the rotor field. Some alternators have a capacitor mounted on them. The capacitor protects the rectifier from high voltages. It also suppresses electrical noise through a radio, if equipped.

The alternator is connected to the battery through the ignition switch for alternator turn on . Therefore, alternator excitation occurs when the switch is turned on.

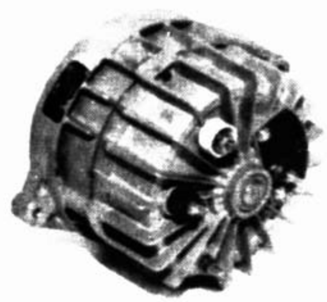
Alternators

The alternators used on these engines have three phase, full-wave, rectified output. They are the brush type. Refer to the Alternator Coverage chart for detailed systems operation information

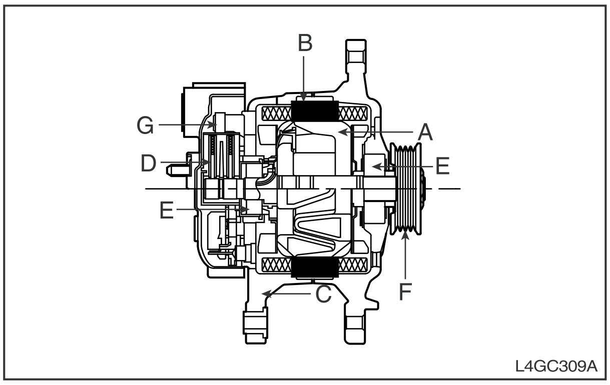
ALTERNATOR COVERAGE	
Alternator Part Number	Manufacturer/ Series
A403795	Valeo
D187478	MICO/K1 Sealed



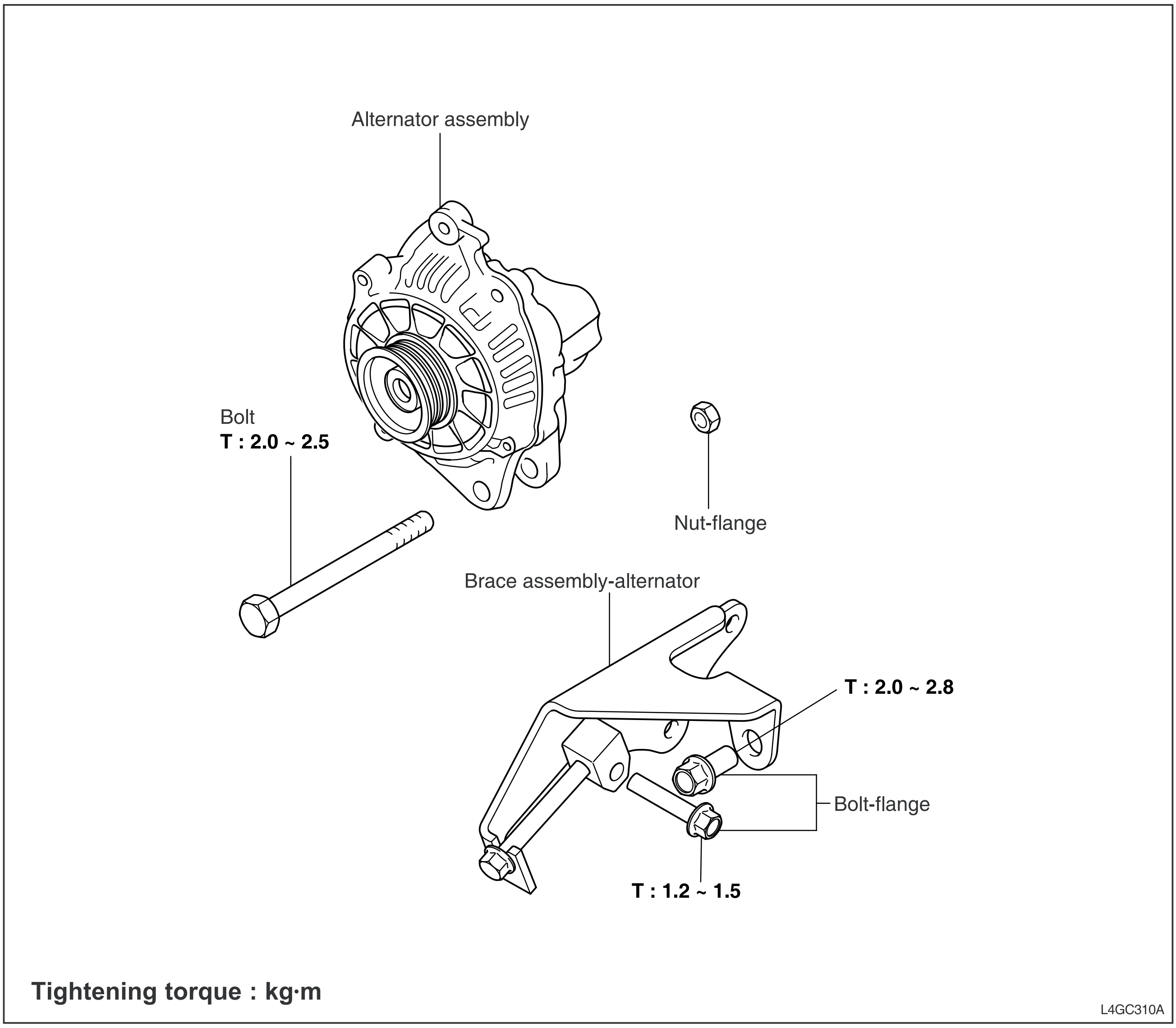
A403795



D187478


B
G
A
D
E
E
C
F
L4GC309A

Components


Alternator assembly
Bolt
T : 2.0 ~ 2.5
Nut-flange
Brace assembly-alternator
T : 2.0 ~ 2.8
Bolt-flange
T : 1.2 ~ 1.5
Tightening torque : kg·m
L4GC310A

Troubleshooting

Charging system defect is almost caused by lack of pan belt tension and faulty function of wiring, connector, and voltage regulator.
One of most important thing during troubleshooting of charging system is determining the reason between overcharging and lack of charging. So, prior to inspection of alternator, check the battery for charging. Faulty alternator causes the following symptoms.

1. Faulty battery charging

1) IC regulator fault(Short circuit)

2) Field coil fault

3) Main diode fault

4) Auxiliary diode fault

5) Stator coil fault

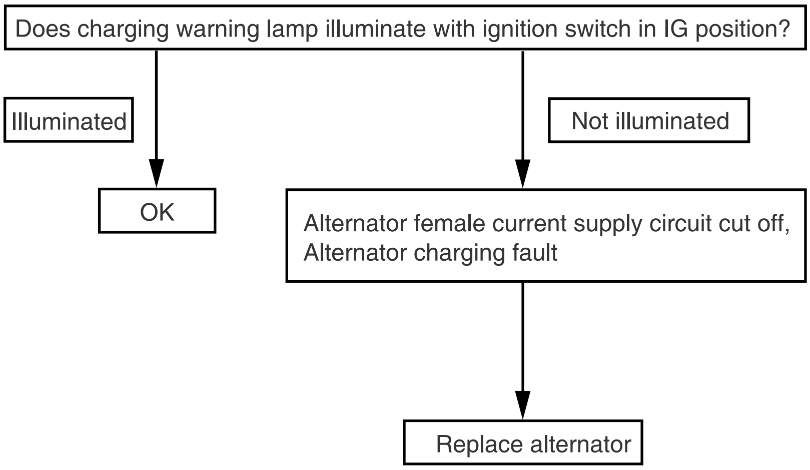
6) Brush contact fault

2. Overcharging : IC regulator fault(Short circuit)
Other faults such as voltage adjusting problem except above symptoms rarely happen.
Refer to the following troubleshooting table

Symptom	Possible cause	Remedy
With ignition switch ON, charging warning lamp does not illuminate	Fuse cut off	Replace
	Bulb burnt out	Replace
	Loose wiring connection	Retighten
	Bad connection of L-S terminals	Inspect and replace wiring, Replace voltage regulator
With the engine started, warning lamp is not turned off (Battery needs often charging)	Loose or worn drive belt	Correct or replace
	Fuse cut off	Replace
	Fuse link cut off	Replace
	Faulty voltage regulator or alternator	Inspect alternator
	Faulty wiring	Repair
	Corrosion or wear of battery cable	Repair or replace
Overcharged	Faulty voltage regulator (Charging warning lamp illuminates)	Replace
	Voltage detection wring fault	Replace
Battery is discharged	Loose or worn drive belt	Correct or replace
	Loose wiring connection	Retighten
	Short circuit	Repair
	Fusible link cut off	Replace
	Ground fault	Repair
	Faulty voltage regulator (Charging warning lamp illuminates)	Inspect alternator
	Battery out	Replace

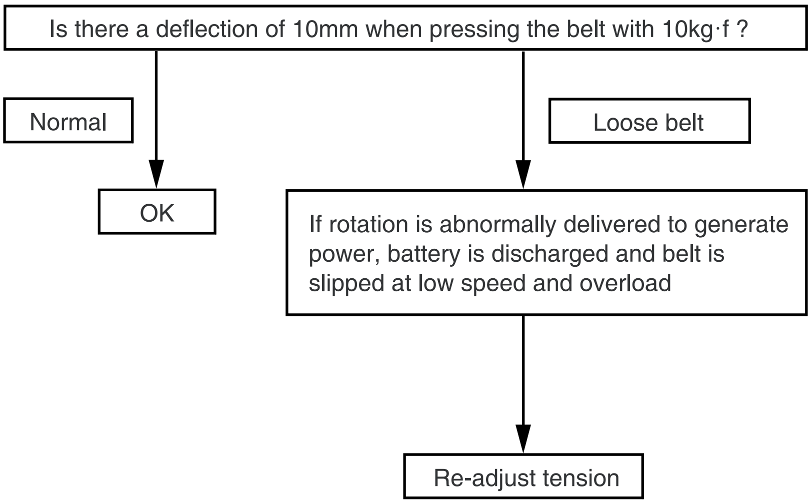
Troubleshooting Procedure

Inspection before Starting



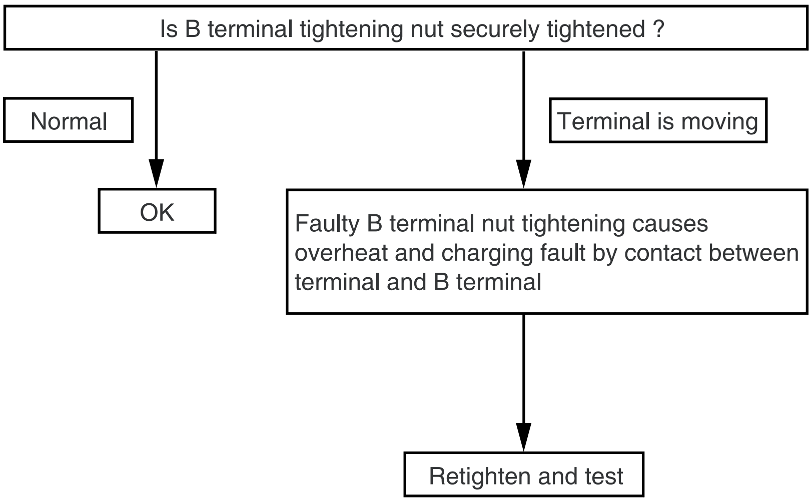
L4GC311A

1. Charging warning lamp inspection.

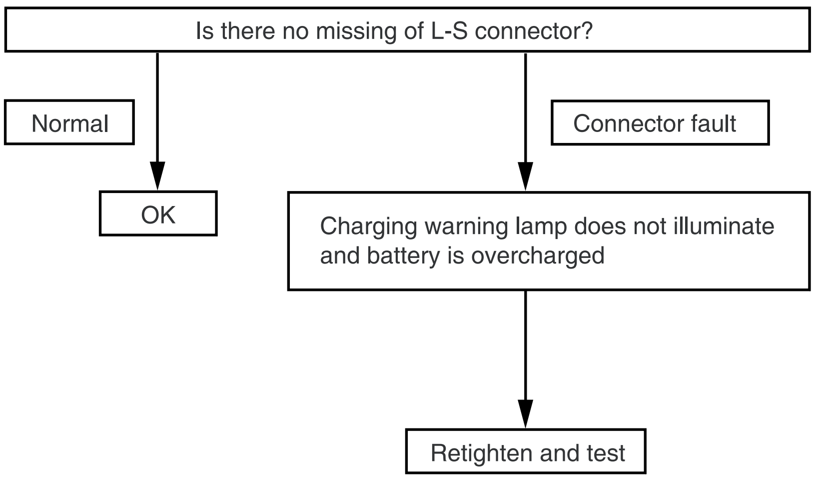


L4GC312A

2. Alternator and drive belt tension inspection.

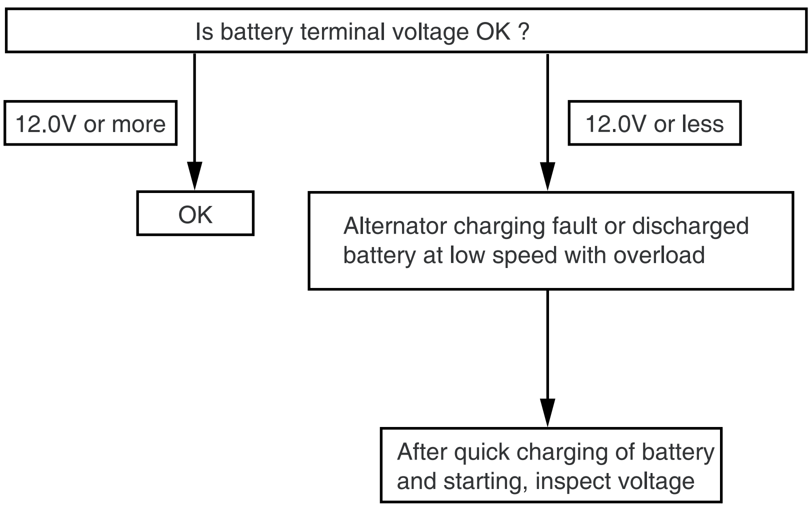


L4GC313A



L4GC314A

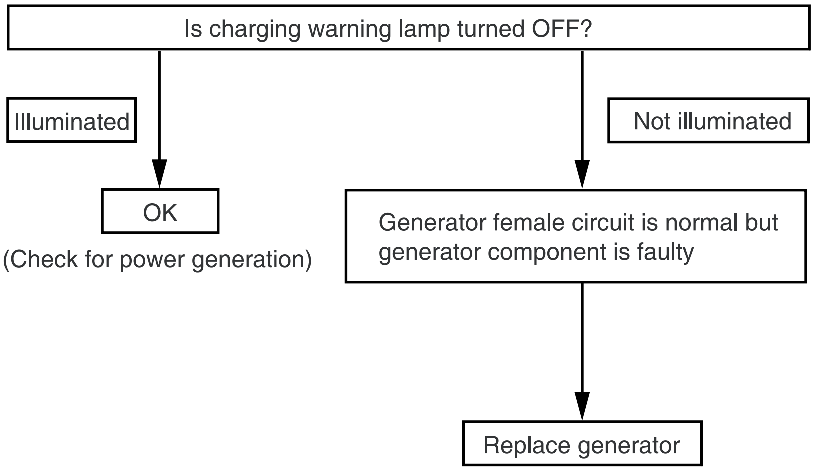
3. Alternator and outer terminal connection inspection.



L4GC315A

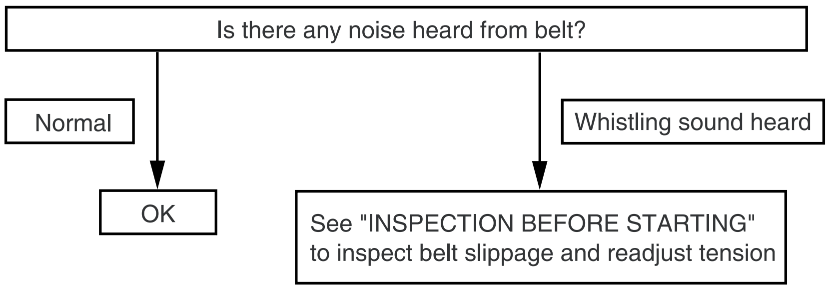
4. Battery outer terminal inspection.

Inspection after Starting



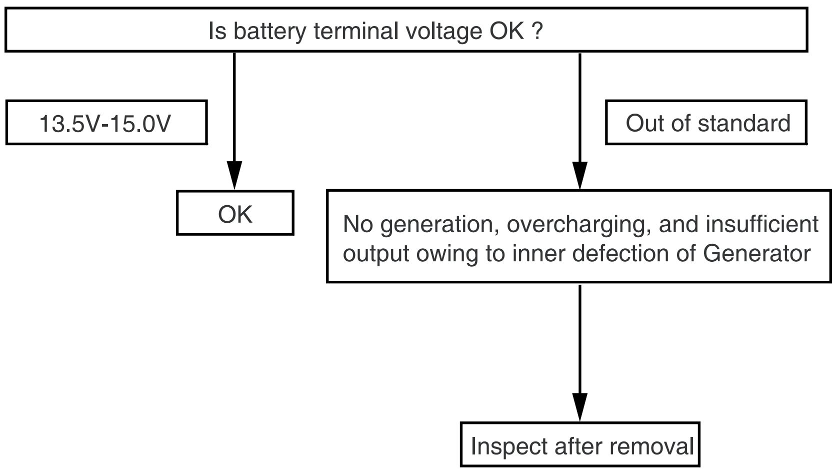
L4GC317A

1. Inspection of alternator charging warning lamp operation test.



L4GC318A

2. When starting, belt slip and noise inspection

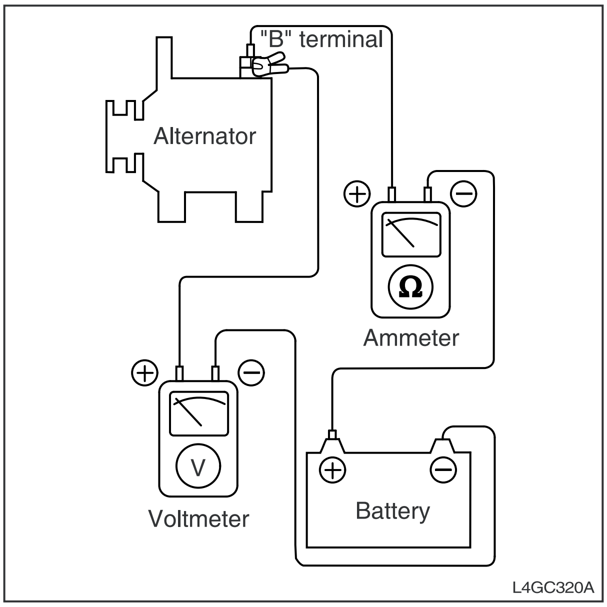


L4GC319A

3. Inspection of battery voltage at idling (At this time charge battery only)

Drop of Electric Pressure Test of Alternator Output Wire

This test is to check that wiring is correctly connected between the alternator "B" terminal and battery (+) terminal.



Preparation

1. Turn the ignition switch OFF.

2. Disconnect the battery ground cable.

3. Disconnect the alternator output wire from the alternator "B" terminal.

4. Connect a DC ampere meter (0-100A) between the terminal and the disconnected output wire. Connect (+) lead wire to the terminal "B" and (-) lead wire to the disconnected output wire.

NOTE: In case of using a clamp type ammeter, it is possible to measure current without disconnecting the harness.

5. Connect a digital voltmeter between the alternator "B" terminal and the battery (+) terminal. Connect (+) lead wire to the terminal and (-) lead wire to the battery (+) terminal.

6. Connect the battery ground cable.

7. Be sure that the hood is opened.

Test

1. Start the engine.

2. Repeating ON and OFF of headlight and small light, adjust the engine speed until an ammeter reads 20A and at that time measure voltage.

Result

1. If voltmeter reading is within the standard, it is normal.

Test voltage	Maximum 0.2V

2. If voltmeter reading is more than the standard, mostly wiring is faulty. In this case, inspect wirings between the alternator and the battery (+) terminal as well as between the alternator "B" terminal and the fusible link.

3. Also prior to re-test, check and repair the connecting part for looseness and the harness for discoloration by overheating.

4. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

5. Disconnect the battery ground cable.

6. Disconnect the ammeter and voltmeter.

7. Connect the alternator output lead wire to the alternator "B" terminal.

8. Connect the battery ground cable.

Output Current Test

This test is to check that the alternator output current is identified with the rated current.

Preparation

1. Prior to test, inspect the following items and repair if necessary.

1) Be sure that the battery installed in the vehicle is normal.(See "Battery")

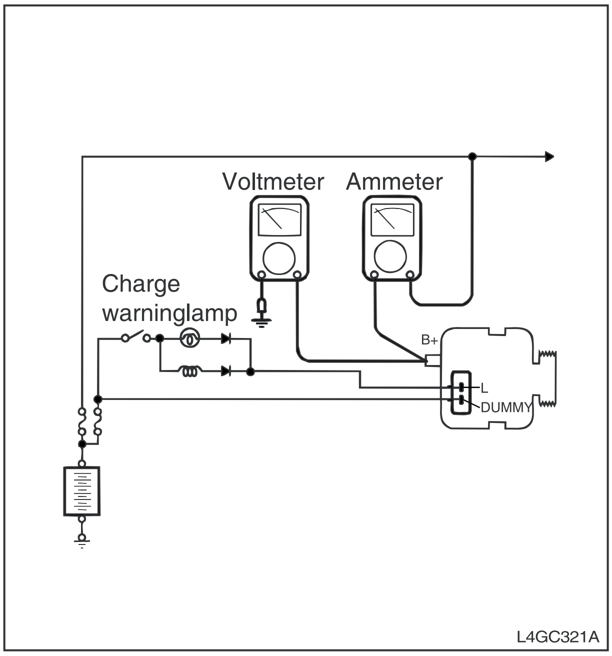
NOTE: When measuring output current, necessarily use a slightly discharged battery. Fully charged battery is not enough to use for correct test owing to insufficient load.

2) Inspect the drive belt for tension.
(See "Engine body")

2. Turn the ignition switch OFF.

3. Disconnect the battery ground cable.

4. Disconnect the alternator output wire from the alternator "B" terminal.



5. Connect a DC ampere meter (0-100V) between "B" terminal and the disconnected output wire. Connect (+) lead wire to the terminal "B" and (-) lead wire to the disconnected output wire.

NOTE: Do not use clips or equivalent owing to high current and Use bolts and nuts to tighten each connecting part securely.

6. Connect a volt meter(0-20V) between "B" terminal and the ground.
Connect (+) lead wire to the alternator "B" terminal and (-) lead wire to the proper position.

7. Connect the engine tachometer and then battery ground cable.

8. Be sure that the hood is opened.

Test

1. Be sure that voltmeter reading is identified with battery voltage.
If voltmeter reading is 0V, it means short circuit of wire between "B" terminal and the battery (-) terminal, fusible link cut off or ground fault.

2. Turn the headlight ON and start the engine.

3. With the engine running at 2,500 rpm, turn ON the high beam headlights, place the heater blower switch at "HIGH" measure the maximum output current using a ammeter.

NOTE: This test should be done as soon as possible to measure the exact maximum current because output current drops rapidly after starting the engine.

Result

1. Ammeter reading should be higher than the limit.
If the reading is low even though the alternator output wire is normal, remove the alternator from the vehicle and inspect it.

Output current limit	70% of rated current

NOTE: The rated output current is represented on the name plate in the alternator body.
Output current varies according to electrical load or temperature of the alternator, so during test, lack of electrical load causes impossibility of measuring the rated output current. In this case, turn on headlight to induce the battery discharging or turn on other lights to increase the electrical load. If alternator temperature or ambient temperature is too high, it is impossible to measure the rated output current, so prior to re-test, necessarily drop the temperature.

Ambient temperature of voltage regulator(℃)	Voltage adjust(V)
-20	14.2 ~ 15.4
20	13.8 ~ 15.0
60	13.4 ~ 14.6
80	13.2 ~ 14.4

2. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

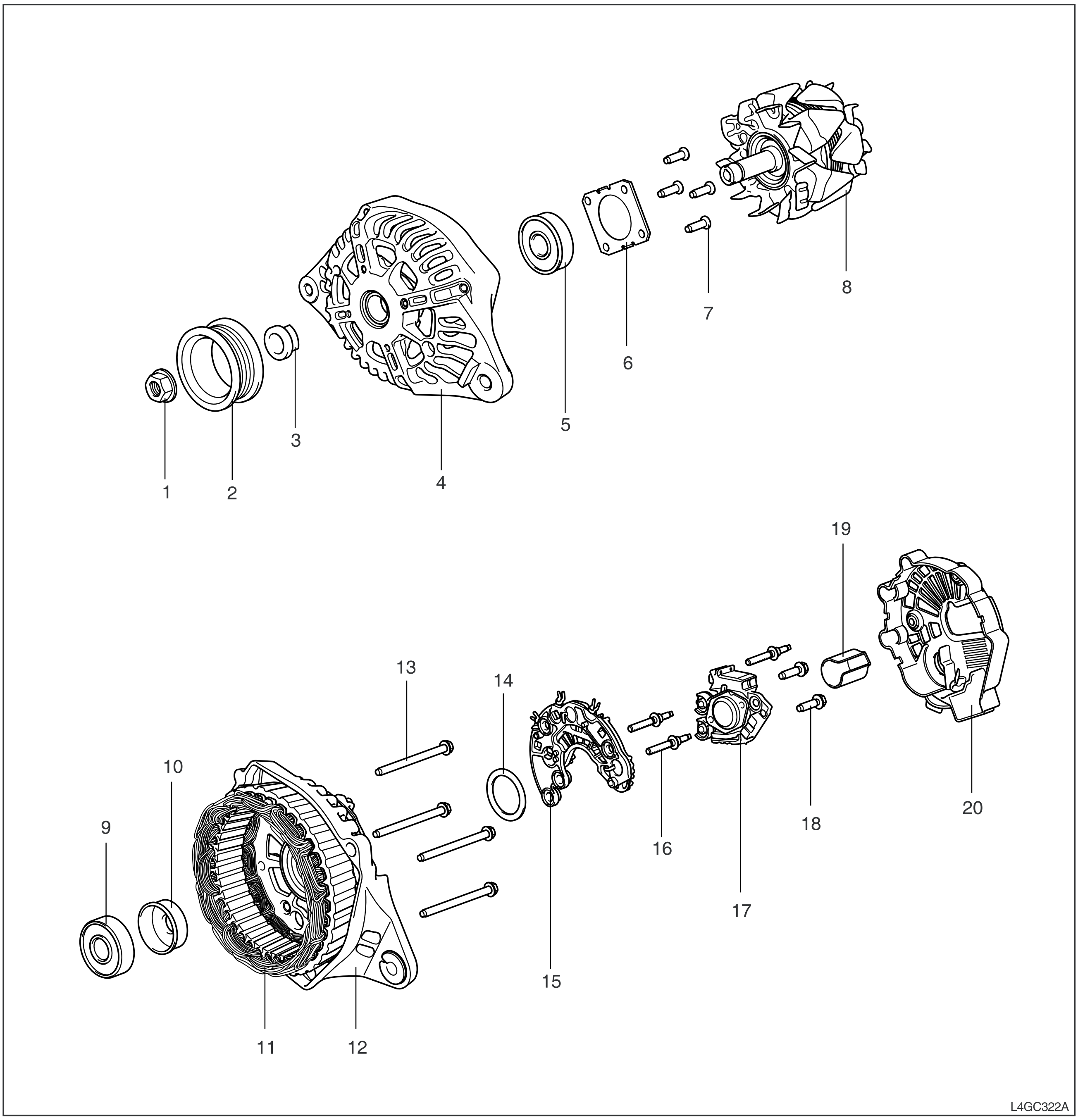
3. Disconnect the battery ground cable.

4. Disconnect the ammeter and voltmeter.

5. Connect the alternator output lead wire to the alternator "B" terminal.

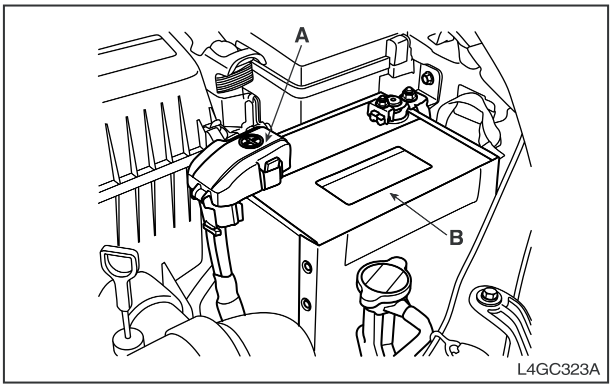
6. Connect the battery ground cable.

Disassembly and Installation

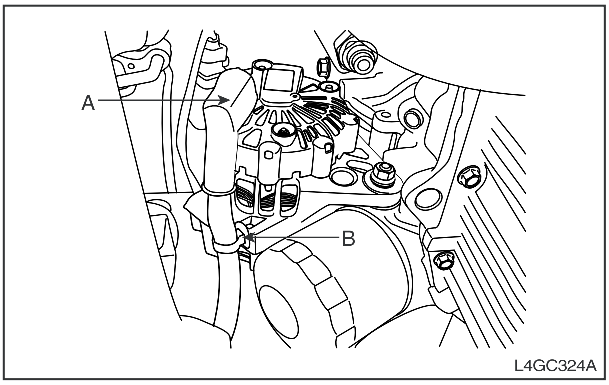


1. Nut	8. Rotor coil	15. Rectifier assembly
2. Pulley	9. Rear bearing	16. Stud bolt
3. Bushing	10. Bearing cover	17. Brush holder assembly
4. Front cover assembly	11. Stator coil	18. Brush holder bolt
5. Front bearing	12. Rear cover	19. Slip ring guide
6. Bearing cover	13. Through bolt	20. Cover
7. Bearing cover bolt	14. Seal	

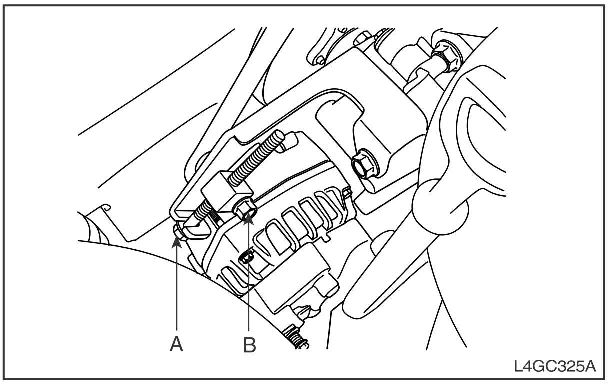
Removal and Installation



1. Disconnect the battery (A) terminal.



2. Disconnect the alternator “B” terminal and then the connector (A). Loosen the clip (B).



3. Loosen the alternator tension adjusting bolt (A) and the alternator fixing bolt (B).

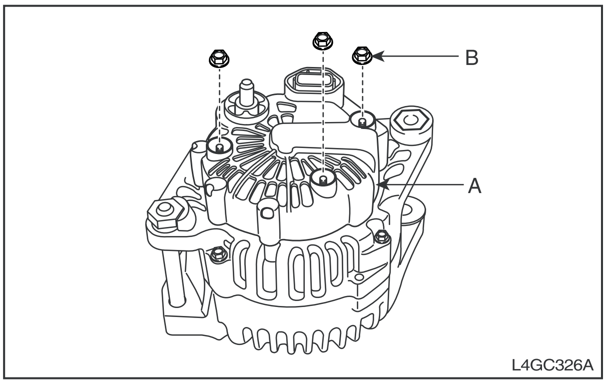
4. Remove the belt by pressing inward the alternator.

5. Remove the alternator brocket.

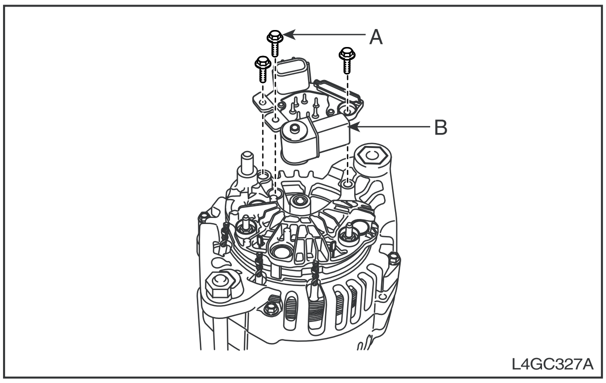
6. Loosen the mounting and remove the alternator assembly.

7. Installation is reverse order of removal.

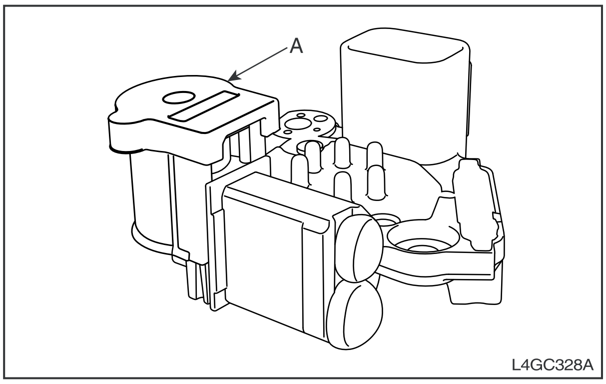
Disassembly



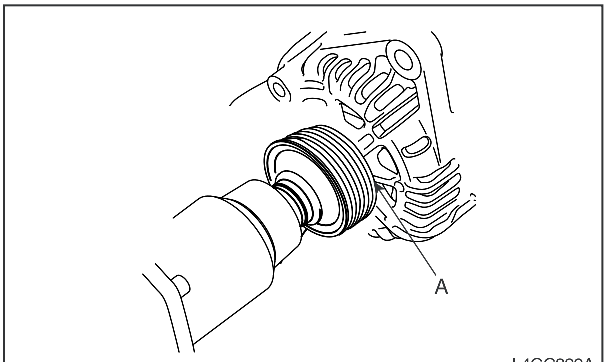
1. After removing the mounting nuts (B), remove the generator cover (A) using a screwdriver.



2. Loosen 3 mounting bolts (A) and disconnect the brush holder assembly (B).

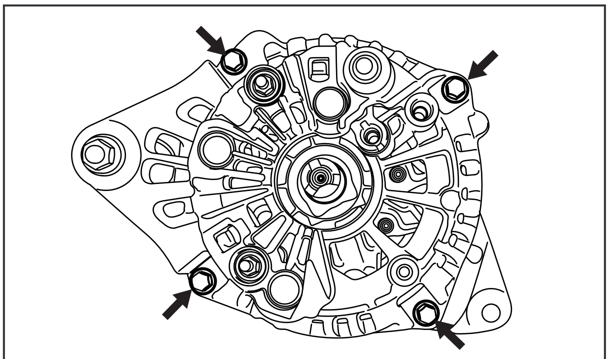


3. Remove the slip ring guide (A).



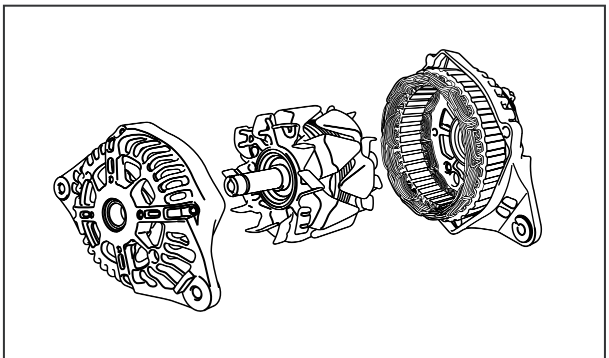
L4GC329A

4. Remove the nut, pulley and spacer.



L4GC330A

5. Loosen 4 through bolts.

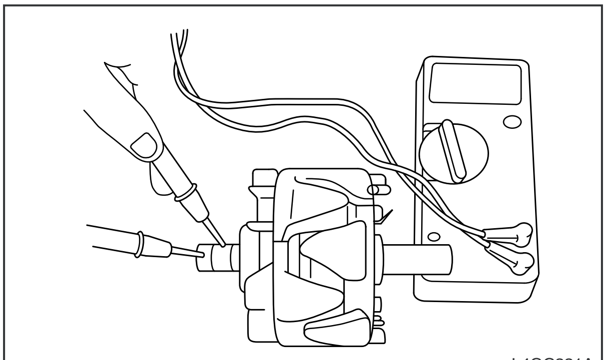


L4GC048A

6. Separate the rotor and cover.

Inspection

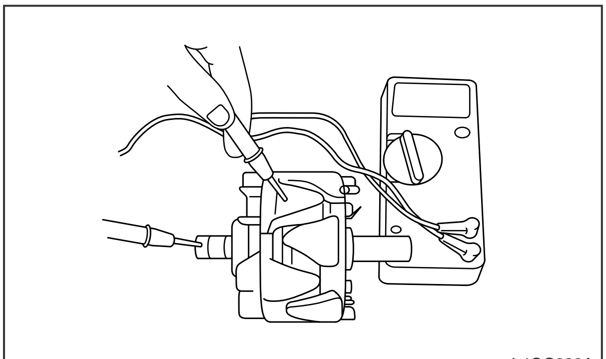
Rotor



L4GC331A

1. Inspect the rotor coil for continuity and check for continuity between slip rings.
If resistance is too low, circuit is short and if the resistance is too high, circuit is opened. So replace the rotor assembly in both cases.

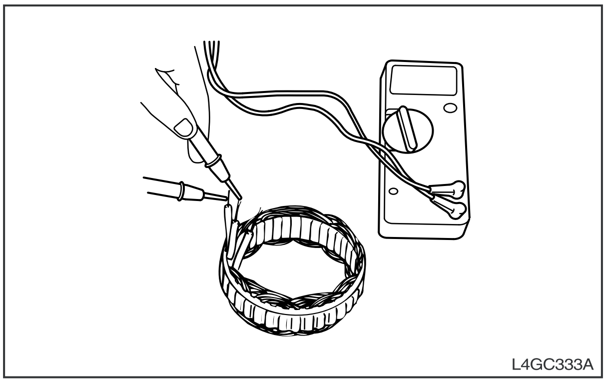
Resistance value	2.5 ~ 3.0Ω(20℃)



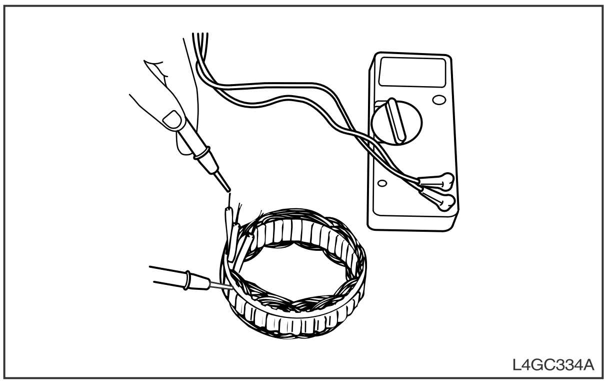
L4GC332A

2. Inspect the rotor coil ground and check continuity between the slip ring and the core, If there is continuity, replace the rotor assembly.

Stator

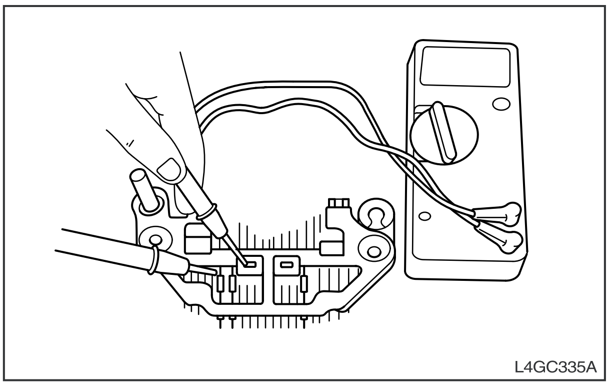


1. Inspect the stator coil for continuity and check continuity between the coil leads. If there is no continuity, replace the stator assembly.

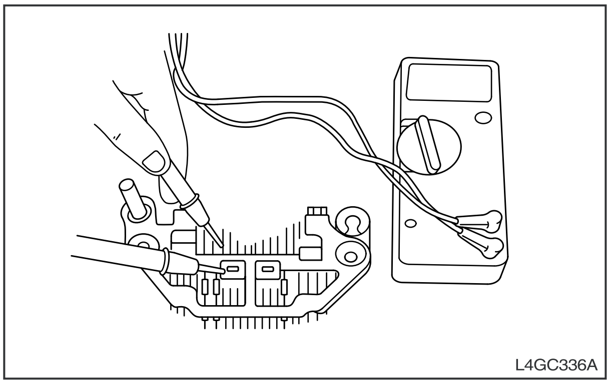


2. Inspect the coil ground and check continuity between the coil and the core. If there is continuity, replace the stator assembly.

Rectifier

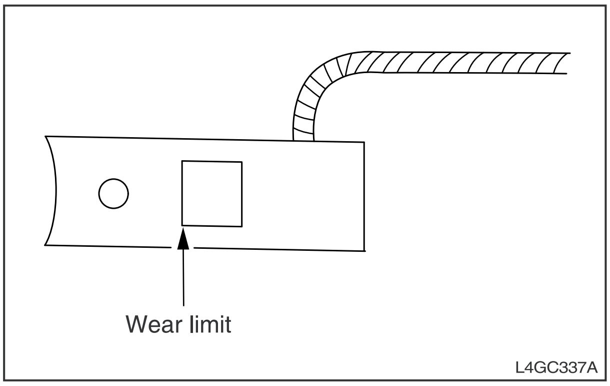


1. (+) rectifier
When inspecting continuity between (+) rectifier and stator coil lead connecting terminal using an ohmmeter, there must have only one direction continuity. If there is both direction continuity, replace the rectifier assembly owing to short circuit of diode.



2. (-) rectifier
When inspecting continuity between (-) rectifier and stator coil lead connecting terminal using an ohmmeter, there must have only one direction continuity. If there is both direction continuity, replace the rectifier assembly owing to short circuit of diode.

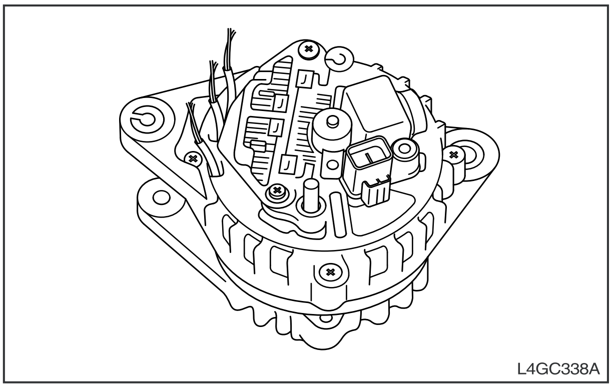
Brush Replacemement



If the brush is worn out to the limit, replace the brush as the following order.

Installation

Installation is the reverse order of disassembly.
Take care of the following items.

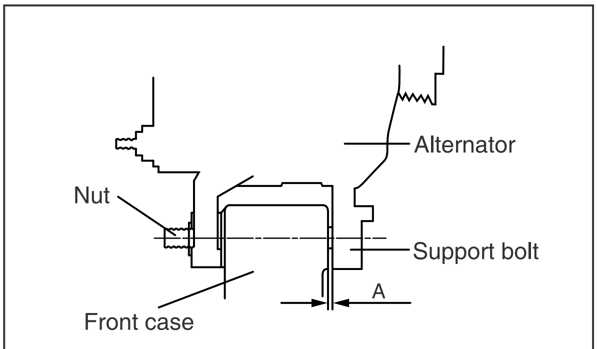


L4GC338A

1. Before installing the rotor to the bracket, insert the wire into the small bore of rear bracket and fix the brush.

2. After installing the rotor, remove the wire.

Installation



L4GC339A

1. After placing the alternator, insert the support bolt. (At this time do not insert the nut.)

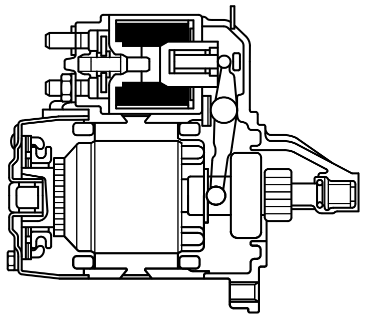
2. After pressing forward the alternator, Contact the alternator front bracket with front case (A) as shown in the illustration.

3. Insert and install the nut by tightening it to the specified torque.

STARTING SYSTEM

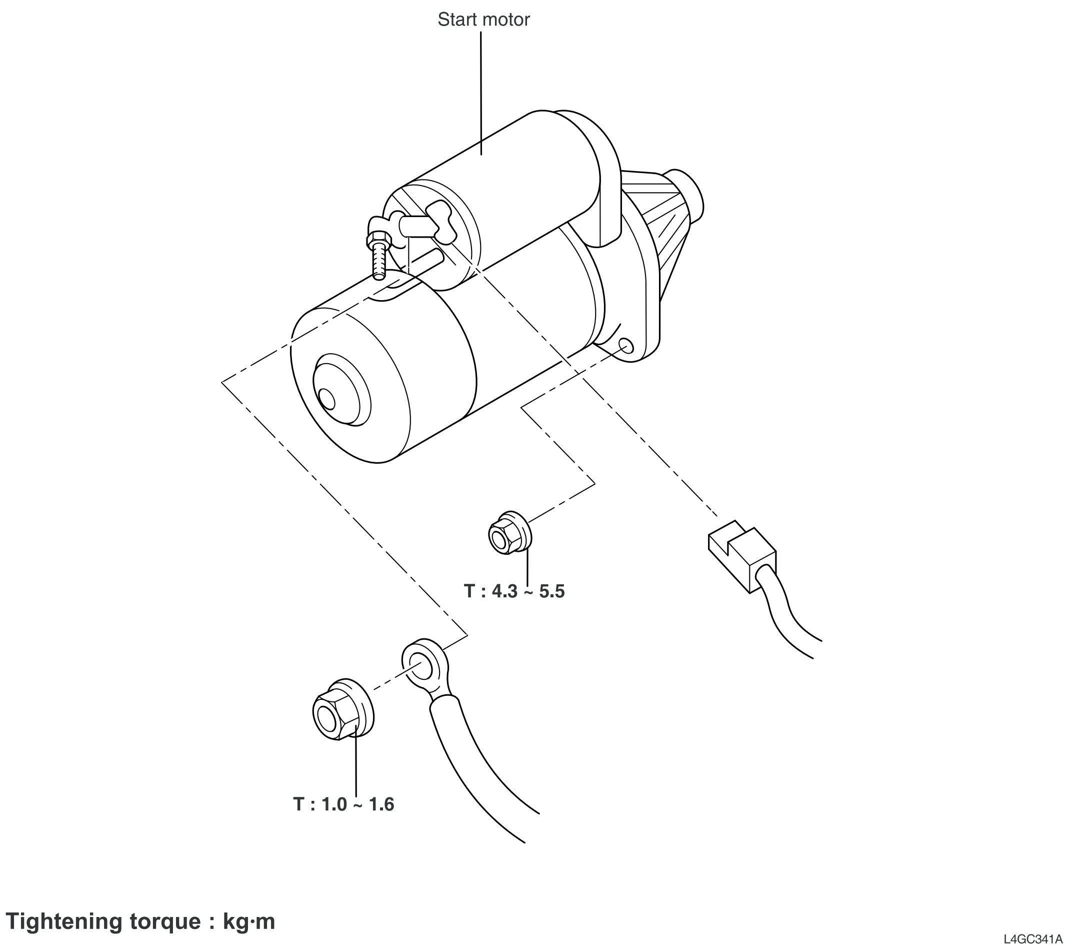
General Description

The starting motor is used to turn the engine flywheel lfast enough to make the engine run. The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor just before the pinion engages the ring gear. This causes the starting motor to rotate. This type of motor "turn on" is a positive shift starting motor. When the engine begins to run, the overrunning clutch portion of the pinion drive prevents damage to the armature caused by excessive speeds. The clutch does this by breaking the mechanical connection. The pinion will stay meshed with the ring gear until the ignition switch is released. A return spring in the overrunning clutch returns the clutch to its rest position.



L4GC340A

Components



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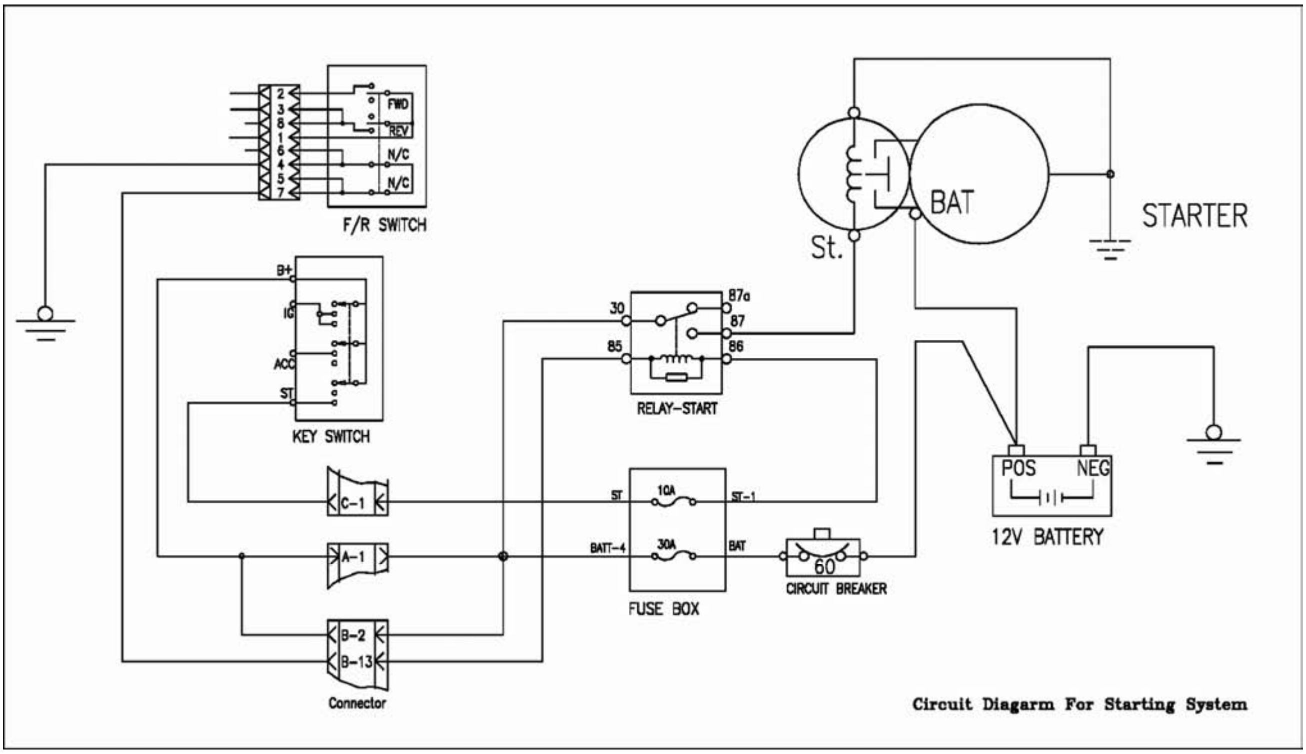


Circuit Diagarm For Starting System

Diagnosis Procedure

The following simplified procedure is intended to help the serviceman determine if a starting motor needs to be removed and replaced or repaired. It is not intended to cover all possible problems and conditions, but to serve only as a guide. The most common 12 volt circuit is shown and discussed.

General Information

All starting systems are made up of four elements. They are the ignition switch, start relay, the starting motor solenoid and starting motor.

Start switches are relatively low current devices. They are rated to switch approximately 5 to 20 amps. Because the coil of a start relay [between test point (1)and (2)] draws about 1 amp, the start switch can easily turn on the start relay and have long life.

The switch contacts of a typical start relay are rated to switch 30 amps. Because the solenoid requires 5 to 20amps the start relay can easily switch this load.

The starting motor solenoid has two functions:

1. Engages the pinion with flywheel.

2. Is a high current switch rated about 1000 amps that actually turns on the starting motor.

The starting motor solenoid has two coils. Pull-in coil(W) draws about 40 amps and hold-in coil (X) requires about 5 amps. The instant the start relay closes, both coils (W) and (X) receive power. Battery voltage is applied to the high end of both coils, at test point (3)which is the start (S) terminal. The low end of hold-in coil (X) is permanently grounded to the ground post or motor housing of the starting motor. Grounding for the low end, test point (4), of pull-in coil (W) is momentary, and takes place through the DC resistance of the starting motor. As soon as magnetic force builds in both coils, the pinion moves toward the flywheel ring gear. The pinion will stop short of engagement of the flywheel ring gear. Only then will the solenoid contacts close to power the starting motor. This temporarily removes the ground from pull-in coil (W), and puts battery voltage on both ends of it while the starting motor cranks. During this period, the pull-in coil is out of the circuit. Cranking continues until power to the solenoid is broken by releasing the ignition switch.

The result of these switches and relays is to permit a 5 amp dash-mounted switch to turn on a 500 to 1000amp motor used to crank an engine. Battery voltage (power) available during cranking varies according to the temperature of the batteries. The following chart is a guide as to what to expect from a normal system.

TYPICALSYSTEM VOLTAGE DURING CRANKING AT VARIOUS AMBIENT TEMPERATURES	
Temperature	12V System
-23 to -7 C (-10 to 20 F)	6 to 8 Volts
-7 to 10 C (20 to 50 F)	7 to 9 Volts
10 to 27 C (50 to 80 F)	8 to 10 Volts

Figure 1

The next chart shows maximum acceptable voltage loss in the high current battery circuit feeding the starting motor. These values are maximums for machines of approximately 2000 SMH and up. Newer machines would be less than those shown.

MAXIMUM ACCEPTABLE SYSTEM VOLTAGE DROPS DURING CRANKING	
Circuit	12V System
Battery(-) post to starting motor (-) terminal	0.7 Volts
Battery (+) post to solenoid (+) terminal	0.5 Volts
Solenoid Bat terminal to solenoid Mtr terminal	0.4 Volts

Figure 2

Voltages greater than those shown are most often caused by loose and/or corroded connections or defective switch contacts.

Diagnosis Procedure

TOOLS NEEDED	
Digital Multimeter or Equivalent	1
DC Clamp-On Ammeter or Equivalent	1

NOTICE

Do not operate the starting motor for more than 30seconds at a time. After 30 seconds, the cranking must be stopped for two minutes to allow the starting motor to cool. This will prevent damage to the starting motor due to excessive heat buildup.

If the starting motor cranks real slow or does not crank at all, do the following procedure:

1. Measure battery voltage at the battery posts with the multimeter while cranking or attempting to crank the engine. Make sure to measure the battery posts. Do not measure the cable post clamps.

2. Is battery voltage equal to or greater than shown in Figure 1?

- If the battery voltage is correct, go to Step 3.
- If the battery voltage is too low, Charge or replace the battery.

NOTE: Alow battery can be caused by battery condition or a shorted starting motor.

3. Measure current draw on the (+) battery cable between the battery and the starting motor solenoid with the clamp-on ammeter. The maximum current draw allowed is 350 Amp. At temperatures below27°C (80°F), the voltage will be less and the current draw will be higer. If current draw is too much, the starting motor has a problem and must be removed for repair or replacement.

NOTE: If voltage at the battery post is within approximately 2 volts of the lowest value in the applicable temperature range of Figure1 and if the large starting motor cables get hot, then the starting motor has a problem and the Ammeter test is not needed.

4. Measure starting motor voltage from test point (4) to (5) with the multimeter while cranking or attempting to crank the engine.

5. Is voltage equal to or greater than shown in Figure1?

- If the starting motor voltage is correct, the battery and starting motor cables down to the motor are within specifications. Go to Step 8.

- If the starting motor voltage is low, the voltage drop between the battery and the starting motor is too great. Go to Step 6.

6. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with maximum voltage drops allowed in Figure 2.

7. Are all the voltages within specifications ?

- If the voltage drops are correct, go to Step 8, to check the engine.

- If the voltage drops are too high, repair and/ or replace the faulty electrical component.

8. Rotate the crankshaft by hand to make sure it is not locked up. Check oil viscosity and any external loads that would affect engine rotation.

9. Is the engine locked up or hard to turn ?

- If it is, repair the engine as required. If the engine is not hard to turn, go to Step 10.

10. Does the starting motor crank?

- If it does crank, remove the starting motor for repair and/or replacement.

- If it does not crank, check for blocked engagement of the pinion and flywheel ring gear.

NOTE: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

Start Relay Tests

Relay

1. Put the multimeter on the 200 ohm scale.

2. Put the multimeter lead to the 85 and 86 terminals.

3. The indication on the meter must be 82 5 ohms. If the indication is not correct, the start relay must be replaced.

4. Put the multimeter leads to the 30 and 87 terminals.

5. The indication must be "OL"(Over Load). If the indication is not correct, the start relay must be replaced.

6. Connect WH wire to 86 and BK wire to 85 terminal with the ignition switch to start position. Put the meter lead to 30 and 87 terminal.

7. The indication must be Zero ohm. If the indication is not correct the start relay must be replaced.

Troubleshooting

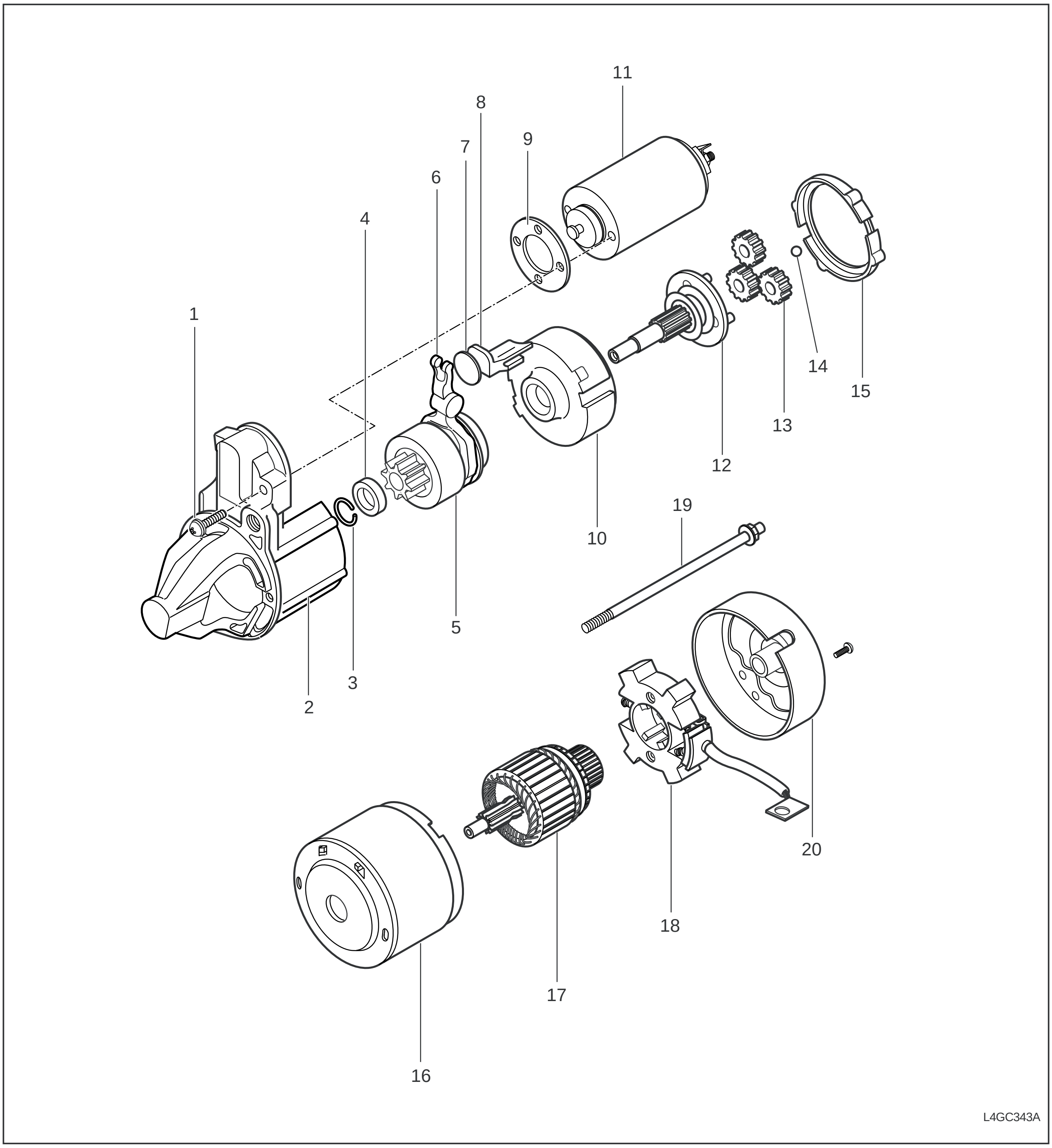
Starting system problem can be classified into “Start motor is not operating”, “Start motor is operating but engine is not starting” , and “There is a lot of time taken to start engine”.

When the starting system has problems, before removing the start motor, find where the problem happens. Generally if it is difficult to start, there are problems in ignition system, fuel system, and electrical system. In this case, necessarily inspect and repair step by step, or the same problem will happen.

Symptom	Possible cause	Remedy
Impossible cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Inhibitor switch fault (With A/T)	Adjust or replace
	Short circuit of fusible link	Replace
	Start motor fault	Repair
	Ignition switch fault	Replace
Slow cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Start motor fault	Repair
Continuous rotating of start motor	Start motor fault	Repair
	Ignition switch fault	Replace
Start motor is rotating but engine is not cranking	Short circuit of wiring	Repair
	Worn or broken pinion gear tooth or motor fault	Repair
	Worn or broken ring gear tooth	Replace flywheel ring gear or torque converter

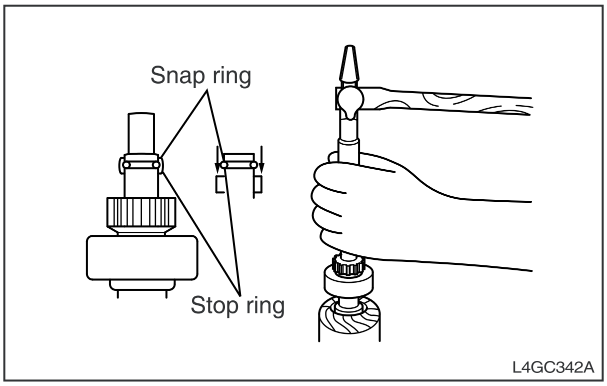
Starter

Components



1. Screw	6. Lever	11. Magnetic switch	16. Yoke assembly
2. Front bracket	7. Plate	12. Planetary gear holder	17. Armature
3. Stop ring	8. Packing B	13. Planetary gear	18. Brush holder
4. Stopper	9. Shim	14. Ball	19. Through bolt
5. Overrunning clutch	10. Internal gear	15. Packing A	20. Rear bracket

Removal and Installation



1. Disconnect the battery ground cable.

2. Remove the speedometer cable.

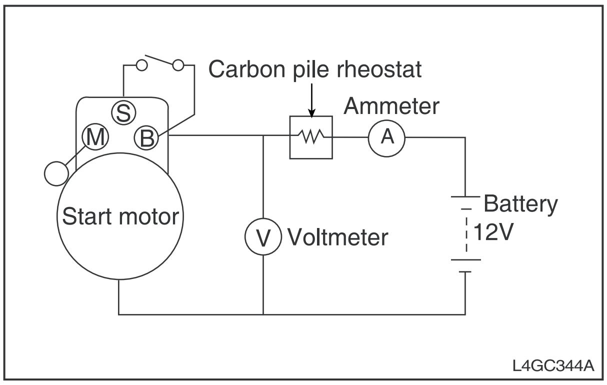
3. Separate the start motor connector and terminal.

4. Remove the start motor assembly.

5. Installation is the reverse of removal.

Inspection (After Removal)

Insection of Pinion Clearance



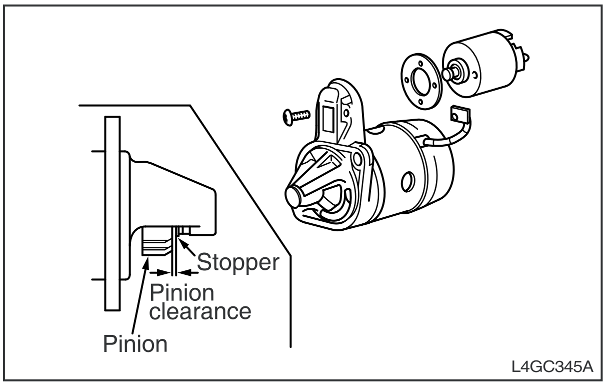
1. Disconnect the wire from "M" terminal.

2. Connect a 12V battery between "S" terminal and "M" terminal.

3. If the switch is turned ON, the pinion is moving.

⚠ CAUTION

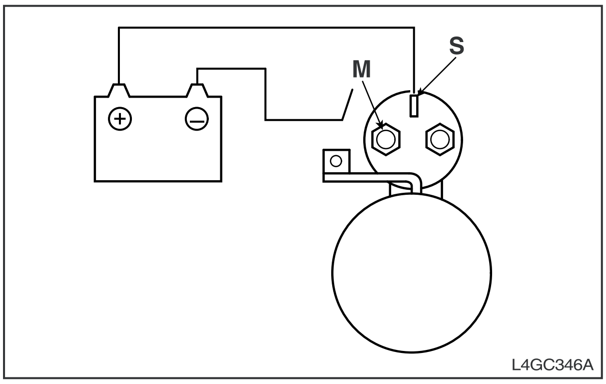
This test should be done as soon as possible not to damage the coil (in 10 seconds).



4. Measure clearance between the pinion and stopper using a feeler gauge. If the measured value is out of the standard, adjust clearance by adding or removing the washer between the magnetic switch and front bracket.

Pinion clearance	0.5 ~ 2.0㎜

Pull in Test of Magnetic Switch



1. Disconnect the connector from "M" terminal.

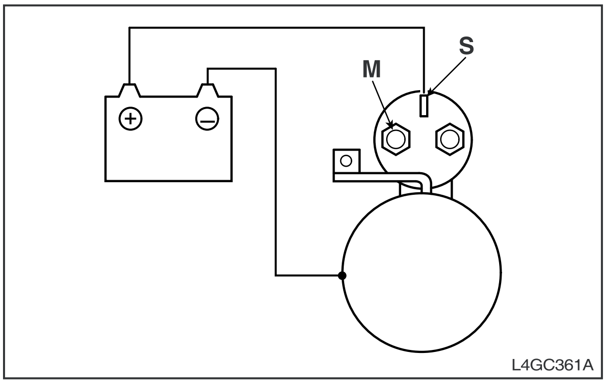
2. Connect a 12V battery between "S" terminal and "M" terminal.

⚠ CAUTION

This test should be done as soon as possible not to damage the coil (in 10 seconds).

3. If the pinion is moving outward, the coil is normal, if or not, replace the magnetic switch.

Hold in Test of Solenoid



1. Disconnect the connector from “M” terminal.

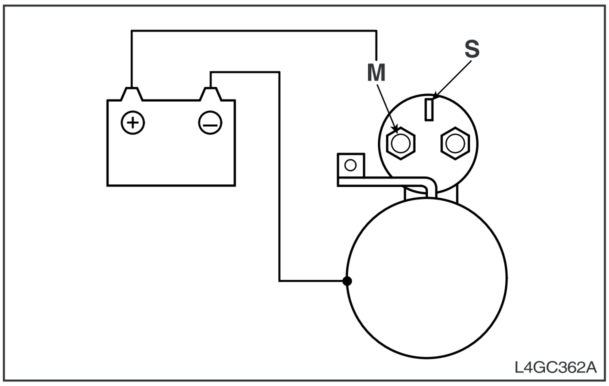
2. Connect a 12V battery between “S” terminal and “M” terminal.

⚠ CAUTION

This test should be done as soon as possible not to damage the coil (in 10 seconds).

3. If the pinion is moving outward, the coil is normal, if the pinion is moving inward, replace the magnetic switch owing to open-circuit.

Return Test of Solenoid



1. Connect the connector from “M” terminal.

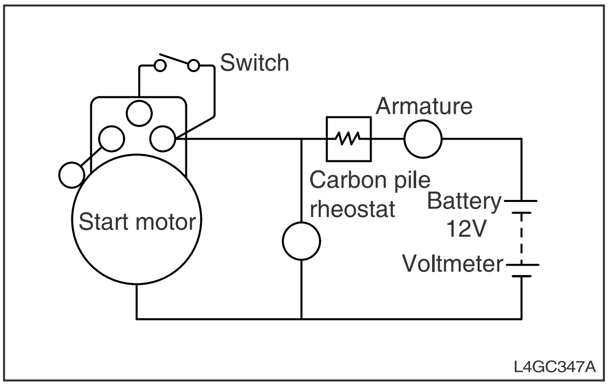
2. Connect a 12V battery between “S” terminal and “M” terminal.

⚠ CAUTION

This test should be done as soon as possible not to damage the coil (in 10 seconds).

3. When releasing after pulling the pinion outward, if the pinion is returned to native position, it is normal, if or not, replace the solenoid valve.

Performance Test (with NO-LOAD)

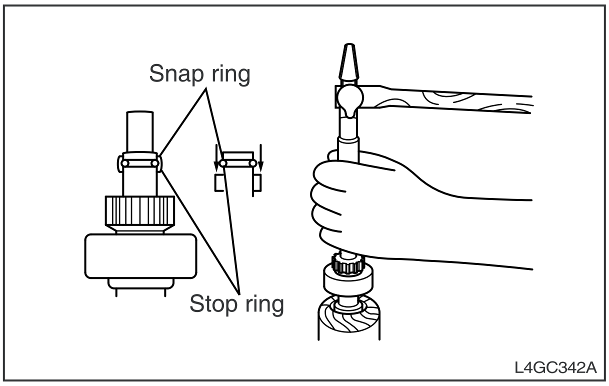


1. Connect a 12V battery to the start motor.

2. To operate the start motor with no load, turn the switch ON. If the operating speed and current measured are identified with the standard, the start motor is normal. If the operating speed is insufficient or the current is excessive, it is because of excessive friction resistance. And the low current or lack of operating speed is because of faulty contact or open circuit between the brush and the rectifier or between the welding points.

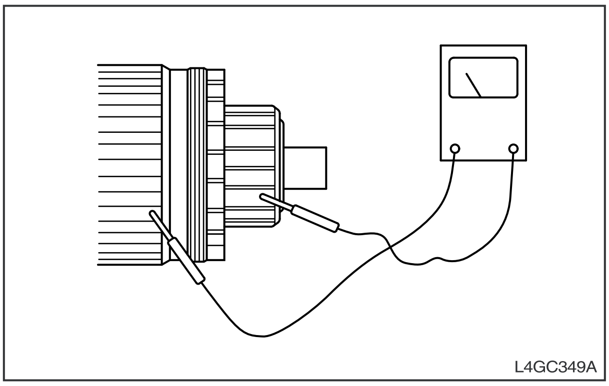
Speed	Minimum 3,000rpm
Current	Maximum 60A or less

Disassembly

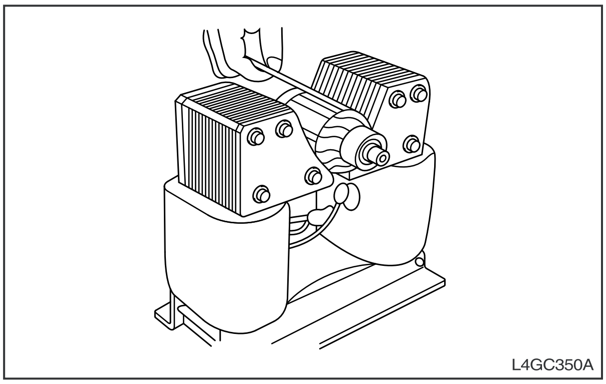


To remove the overrunning clutch from the armature shaft, remove the stop ring. Remove the stop ring by moving it to the pinion side, and then remove the stop ring from the shaft.

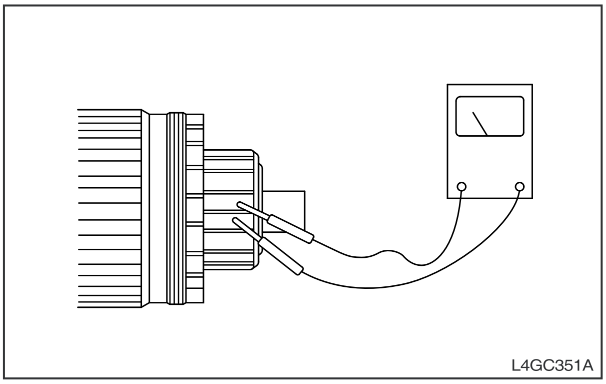
Inspection (After Disassembly)



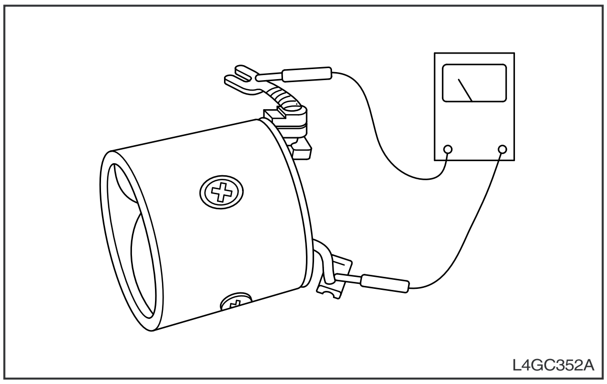
1. Ground Test of Armature Coil.
Check continuity between the commutator and the armature coil using a circuit tester. If there is continuity, replace the rotor assembly.



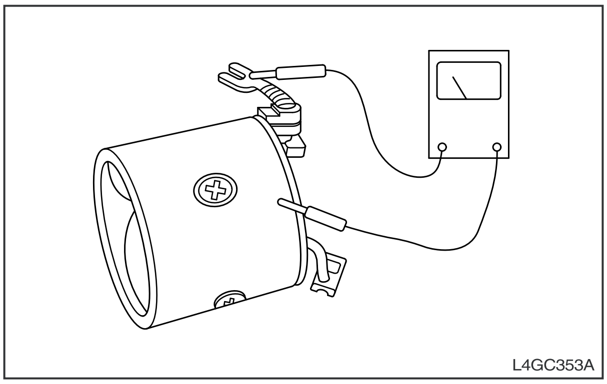
2. Short Circuit Test of Armature Coil.
Inspect the armature coil in the growler and if there is short circuit, replace the coil. During core rotation, if the blade attached in the core is vibrated, the armature is short.



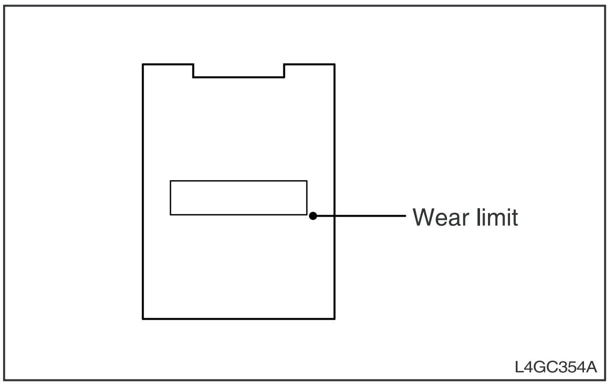
3. Open Circuit Test of Armature Coil.
Check continuity between the commutator segments using a circuit tester. If there is no continuity, replace the armature assembly owing to open circuit of commutator segment.



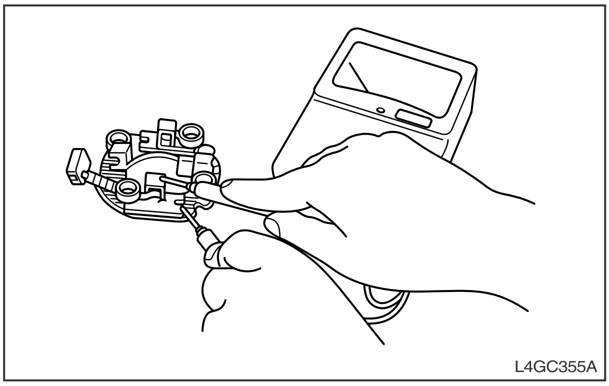
4. Open Circuit Test of Field Coil.
Check continuity of the field coil using a circuit tester. If there is no continuity, replace the field coil assembly owing to open circuit of the field coil.



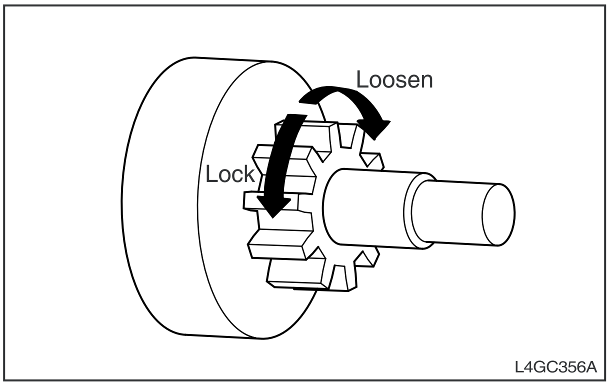
5. Ground Test of Field Coil.
With the yoke field coil installed, inspect continuity between the field coil and the yoke, if there is continuity, replace the field coil.



6. Brush.
If the brush is worn out to the limit, replace the brush.



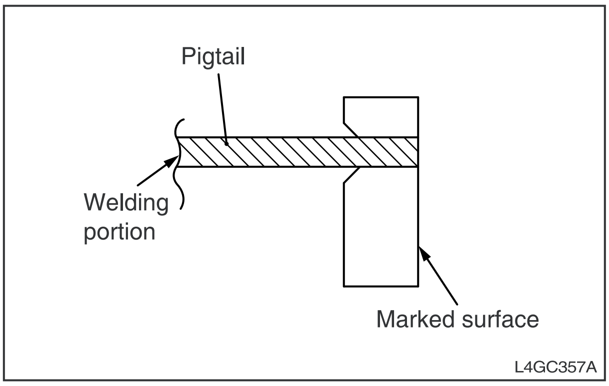
7. Brush Holder
Check continuity between the (+) side brush holder and the base. If there is continuity, replace the brush holder assembly.



8. Overrunning Glutch.

1) Check the pinion and spline teeth for wear and damage and replace it if necessary. Also, inspect the flywheel for wear and damage.

2) Rotate the pinion. The pinion must be rotated clockwise but counterclockwise.

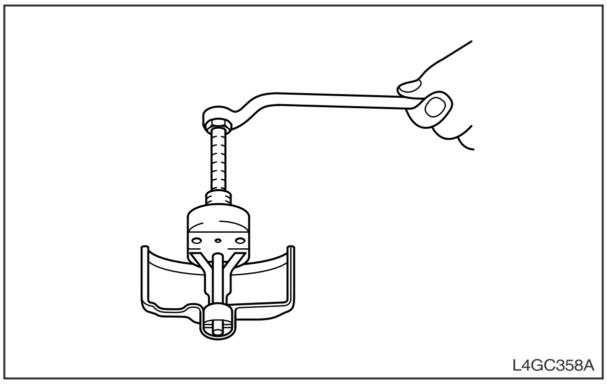


9. Bruch Replacement

1) Remove the worn brush taking care not to damage the pigtail.

2) For better welding, correct the pigtail end with a sand paper.

3) Weld the pigtail end.



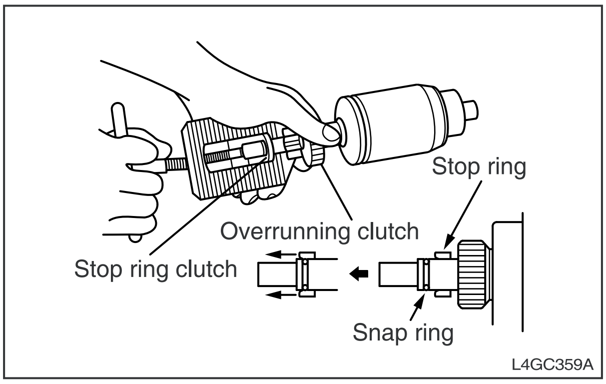
10. Installation of Rear Bracker.

1) Before removing the bushing, measure the bushing press-fit depth.

2) Remove the bushing as shown in the illustration.

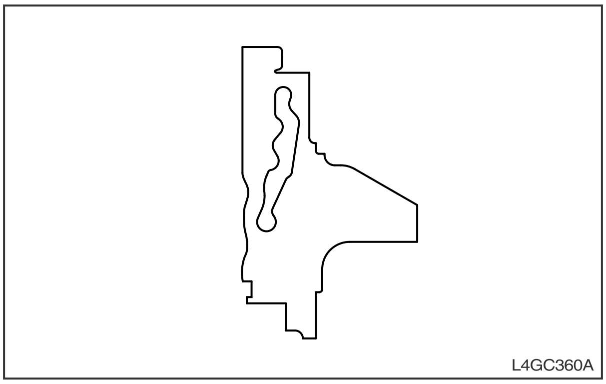
3) Press-fit a new bushing as the depth measured procedure 1).

Assembly



1. Install the overrunning clutch to the armature shaft front end.

2. Install the stop ring and snap ring to the armature shaft front end and completely press the stop ring toward the snap ring.



3. When installing the lever to the front bracket, take care of the direction. If the installation direction is in reverse, the pinion will move outward only.

Chapter 5. ENGINE MANAGEMENT SYSTEM (EMS)

General Information

Specifications

SECM and Sensor/Switch Inputs

Components	Q'ty		Items	Specifications
	G420FE	G420F		
Environmental / Electrical Specifications	None	None	Ambient Operating Temperature Operating Voltage	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc
Engine Control Module (SECM 48)	1	1	Operating Temperature Operating Voltage Operating Environment	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc SECM microprocessor may reset at voltages below 6.3 Vdc On-engine mounting, underhood automotive
Camshaft Position Sensor	1	1	Type Output Voltage	Hall effect sensor 58X
Crankshaft Position Sensor	1	1	Type Tooth wheel	Hall effect sensor 0 – 5 Volts
TMAP Sensor	1	1	MAP sensor Intake Air Temp Sensor	Piezo- Resistivity type 0-5V output Thermistor type (built in MAP sensor) 2.0-3.0kohms at 20°C
LP Fuel Temperature Sensor	1	None	Type Resistance	Thermister 2.5kΩ@20℃ 243Ω@90℃
Oxygen Sensor	2	0(LP) 1(Gas)	Type Output Voltage	Zirconia Sensor (Heated) 0 - 1V
Coolant Temperature Sensor	1	1	Type Resistance	Thermistor Type 1.0-4.0 kohms at 20°C
Acceleration Pedal Angle Sensor	1	1	Type APP1(Low idle) APP2(Low idle) APP1(Hi idle) APP2(Hi idle)	Hall IC 0.4 ± 0.1 V 4.5 ±0.1 V 3.6 ±0.15 V 1.39 ± 0.15 V
Engine Oil Pressure Switch	1	1	Actuation Pressure	0.3 +/- 0.1 kgf/cm^2
Transmission Oil Temperature Switch	1	1	Actuation Temperature	125°C

Components	Q'ty		Items	Specifications
	G420FE	G420F		
Ground speed limit switch	option	option	Type Actuation Pressure	Normal Open 145 ± 28 kPa

Electronic Throttle System

Components	Q'ty		Items	Specifications
	G420FE	G420F		
Electronic Throttle System	1	1	Minimum Electrical Resistance of Throttle Actuator	1.5 ohms

Ignition System Components Specification

Components	Q'ty		Items	Specifications
	G420FE	G420F		
Power TR	4	4	Operating Voltage	5-16V
Ignition Coil Ass'y	4	4	Coil Type Coil Supply Voltage Primary Resistance	Inductive 8-16 Vdc 0.71 ohm +/- 9%
Spark Plug	4	4	Material Air Gap	Platinum spark plug 0.7-0.8 mm

LP Fuel Components Specification

Components	Q'ty		Items	Specifications
	G420FE	G420F		
LP Fuel System Requirements	-	-	Operating Temperature LPG Composition Requirements	-20 °F to 221°F [-29 °C to 105 °C] HD5 / HD10 LPG. Failure to use fuel compliant with HD5 or HD10 standards will void the user warranty.
LP Fuel Filter	1	1	Fuel Filter Micron Size	40 micron
LP Fuel Lock-off	1	1	Electrical Resistance	20~25Ω
N-2007 LP Regulator For G420FE	1	None	Fuel Supply Pressure Fuel Inlet Fitting Fuel Outlet Fitting Fuel Supply Temperature at Tank Outlet Primary Pressure Tap Max Flow Coolant Flow to Vaporizer Fuel Outlet Pressure Setpoints Mounting	10 psi to 250 psi (68.95 kPa to 1723.69 kPa) 1/4" NPT Two 3/4" NPT fittings with one plugged and one 1/8" NPT fitting with plug -20 °F to 120 °F [-29 °C to 49 °C] 1/8" NPT with plug 50 lbm/hr LPG > 1.0 gpm/100bhp, equipped with 140 °F (60 °C) thermostat -0.7 ± 0.2 inH2O @ 1.7 lbm/hr LPG (-1.744 ± 0.498 mbar) @ 1.7 lbm/hr LPG) -2.0 ± 0.2 inH2O @ 50 lbm/hr LPG (-4.982 ± 0.498 mbar) @ 50 lbm/hr LPG) Regulator should be installed with centerline of outlet at least 15° below horizontal to permit drainage of any liquid precipitates from LPG fuel. Diaphragm should be vertically oriented.

Components	Q'ty		Items	Specifications
	G420FE	G420F		
N-2001 LP Regulator For G420F	None	1	Fuel Supply Pressure	10 psi to 250 psi (69 kPa to 1724 kPa)
			Fuel Inlet Fitting	1/4" NPT
			Fuel Outlet Fitting	One 3/4" NPT and one 1/8" NPT fitting with plug
			Fuel Supply Temperature At Tank Outlet	-20 °F to 120 °F [-29 °C to 49 °C]
			Primary Pressure Tap	1/8" NPT with plug
			Max Flow	50 lbm/hr LPG
			Coolant Flow to Vaporizer	>1.0 gpm/100bhp, equipped with 140 °F (60°C) thermostat
			Fuel Outlet Pressure Setpoints	-0.5 ± 0.35 inH2O@1.7 lbm/hr LPG (-1.25 ± 0.87 mbar)@1.7 lbm/hr LPG) -1.35 ± 0.5 inH2O@32.1 lbm/hr LPG (-3.36 ± 1.25 mbar)@32.1 lbm/hr LPG)
CA100 Mixer For G420FE	1	None	Fuel	LPG
			Fuel Inlet Fitting	1/2" NPT Fuel inlet fitted with Delphi temperature sensor
			Air Intake Flange	2.25" (57.15mm) ID inlet, four #10-24 screws in 1.94" (49.28mm) square pattern
			Mixer Mounting Flange	1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern
			Reference Pressure Ports	Two 1/8-NPT ports. Pressure readings must be identical within 0.25 inH2O (0.623 mbar) at all airflows.
			Air Valve Vacuum (AVV) Port Size	1/4-28 UNF
			Fuel Inlet Adjustments	None
			Idle Air Adjustment	None
			Mounting	Suitable for on-engine mounting in vertical orientation

Components	Q'ty		Items	Specifications
	G420FE	G420F		
CA100 Mixer For G420F	None	1	Fuel Fuel Inlet Fitting Air Intake Flange Mixer Mounting Flange Reference Pressure Ports Air Valve Vacuum (AVV) Port Size Fuel Inlet Adjustments Idle Air Adjustment Mounting	LPG 1/2" NPT Fuel inlet fitted with Delphi temperature sensor 2.25" (57.15mm) ID inlet, four #10-24 screws in 1.94" (49.28mm) square pattern 1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern 1/4-1/8 NPT ports. Pressure readings must be identical within 0.25 inH_2O (0.623 mbar) at all airflows. 1/4-28 UNF Power valve Idle adjustment screw Suitable for on-engine mounting in vertical orientation
Fuel Trim Valve (FTV)	2	None	Actuator Type Operating Voltage	On/off two-position valve compatible with LPG 8-16 Vdc

Gasoline Fuel Components Specification

Components	Q'ty		Items	Specifications
	G420FE	G420F		
Gasoline System Requirements	None	None	Gasoline Requirements	Unleaded gasoline of 87 octane or higher is recommended
Gasoline Fuel Pump	1	1	Type	Electrical, In-Tank
Gasoline Fuel Filter	1	1	Type	High pressure type (built in Fuel Pump Assembly)
Gasoline Pressure Regulator	1	1	Pressure	350 kPa (49.8 psi) built in Fuel Pump Assembly
Fuel Injector	4	4	Type Coil resistance	Electric-magnetic 14.5 +/- 0.35 ohms

Service Standard

Basic Idle rpm (After warm up)	No Load	750±15 rpm
Ignition Timing (After warm up, at idle)	BTDC 5°±5°	

Sealants

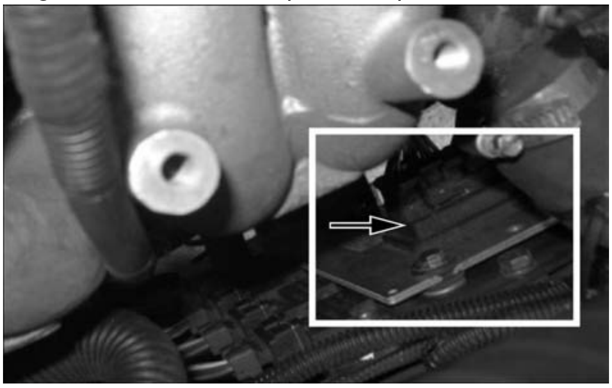
Engine Coolant Temperature Sensor (ECTS) assembly	LOCTITE 962T or equivalent

Tightening Torques

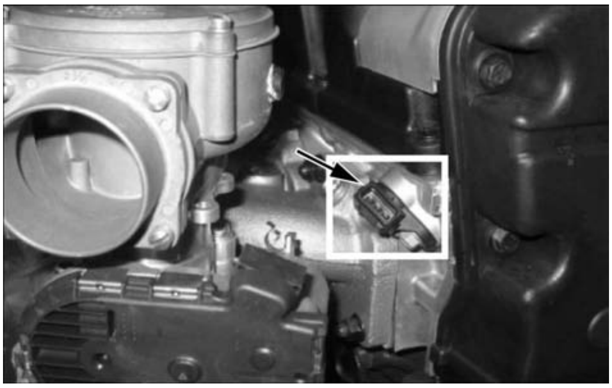
Items	N·m	kgf·m	1bf·ft
Heated Oxygen Sensor (HO2S, Sensor 1)	50 ~ 60	50 ~ 60	36. 2 ~ 43.4
Heated Oxygen Sensor (HO2S, Sensor 2)	50 ~ 60	5.0 ~ 6.0	36.2 ~ 43.4
Crankshaft Position Sensor (CKPS)	4 ~ 6	0.4 ~ 0.6	2.9 ~ 4.3
CKPS target wheel installation screw	10.8 ~ 11.8	1.1 ~ 1.2	8.0 ~ 8.7
Camshaft Position Sensor (CMPS)	4 ~ 6	0.4 ~ 0.6	2.9 ~ 4.3
Engine Coolant Temperature Sensor (ECTS)	15 ~ 20	1.5 ~ 2.0	10.8 ~ 14.5
Delivery pipe installation	19 ~ 28	1.9 ~ 2.8	13.7 ~ 20.3

Component Location

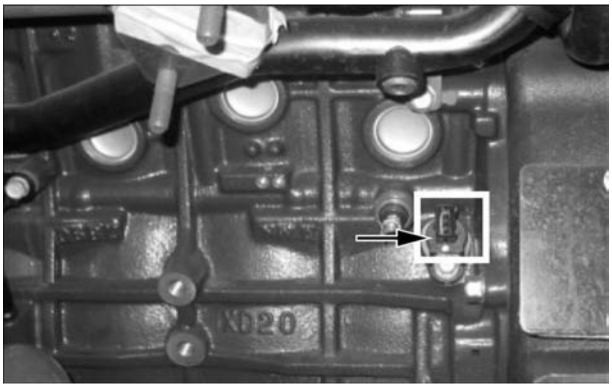
Engine Control Module (SECM48)



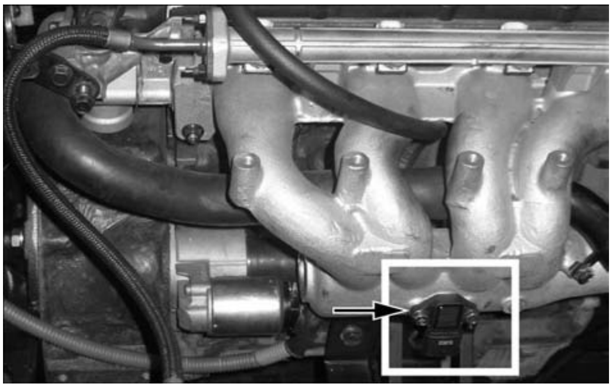
Camshaft Position Sensor



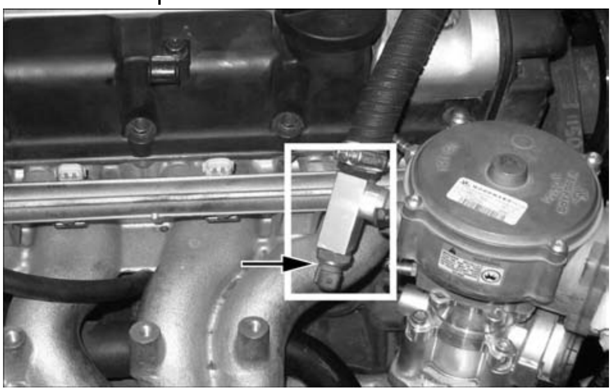
Crankshaft Position Sensor



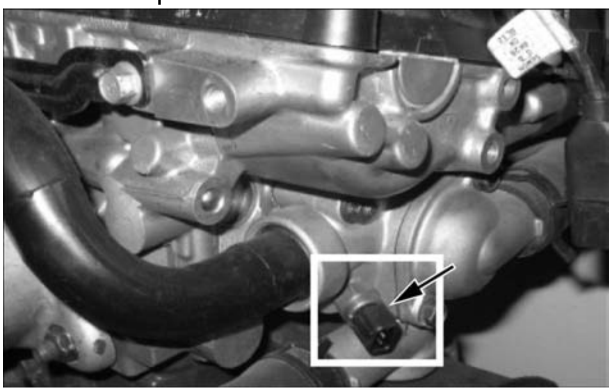
TMAP Sensor



LP Fuel Temperature Sensor

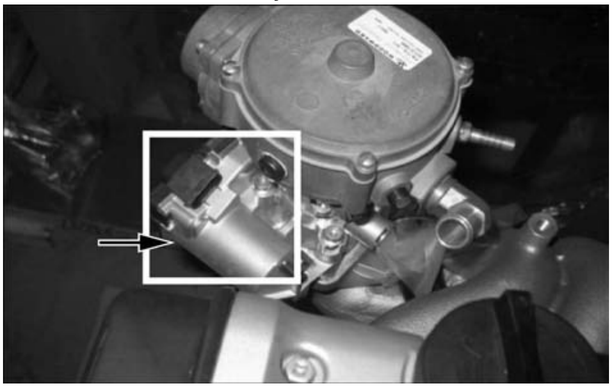


Coolant Temperature Sensor

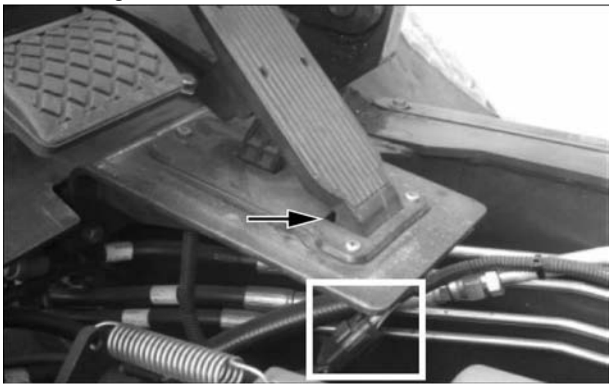


Pre-Catalyst Oxygen Sensor

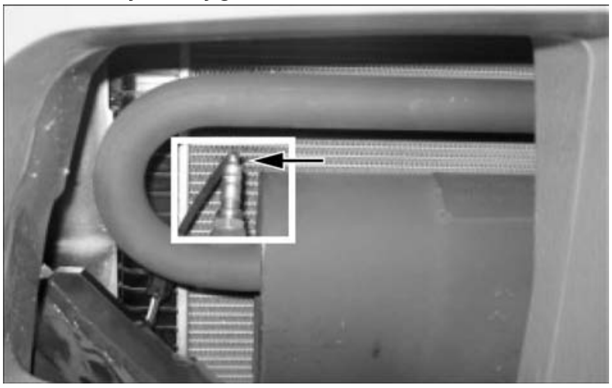
Electronic Throttle Body



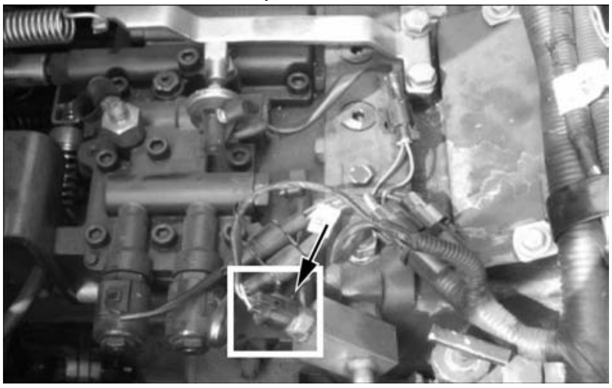
Pedal Angle Sensor



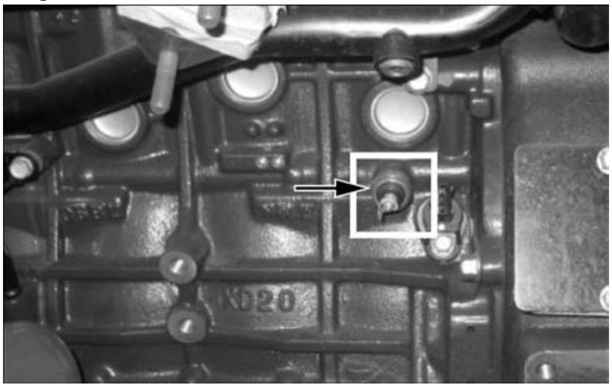
Post-Catalyst Oxygen Sensor



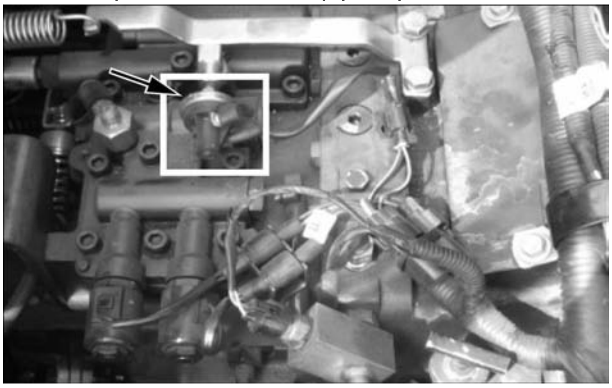
Transmission Oil Temperature Switch



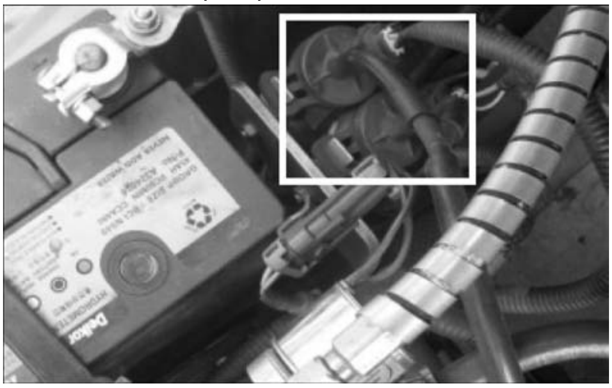
Engine Oil Pressure Switch



Ground speed limit switch (option)

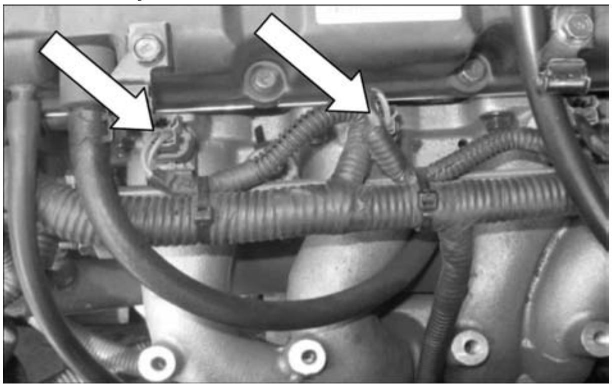


Fuel Trim Valve (FTV)



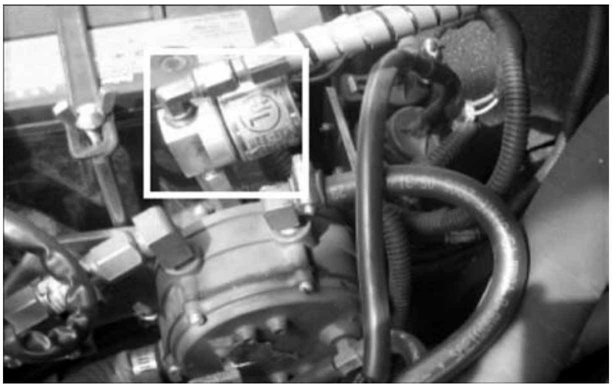
Power TR

Gasoline Injectors and fuel rall

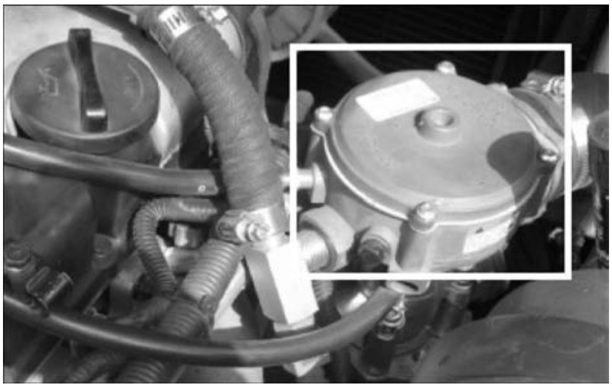


N-2007 LP Regulator

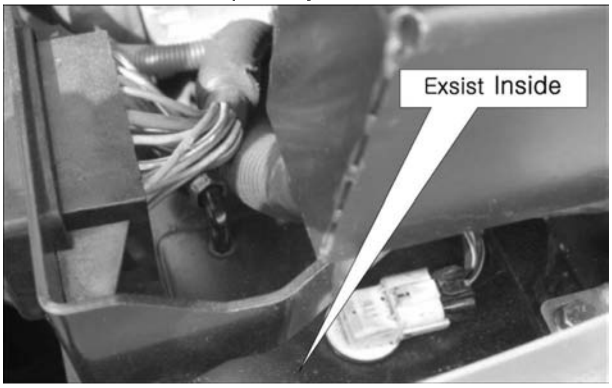
LP Fuel Lock-off



CA100 Mixer



Gasoline Fuel Pump Ass`y



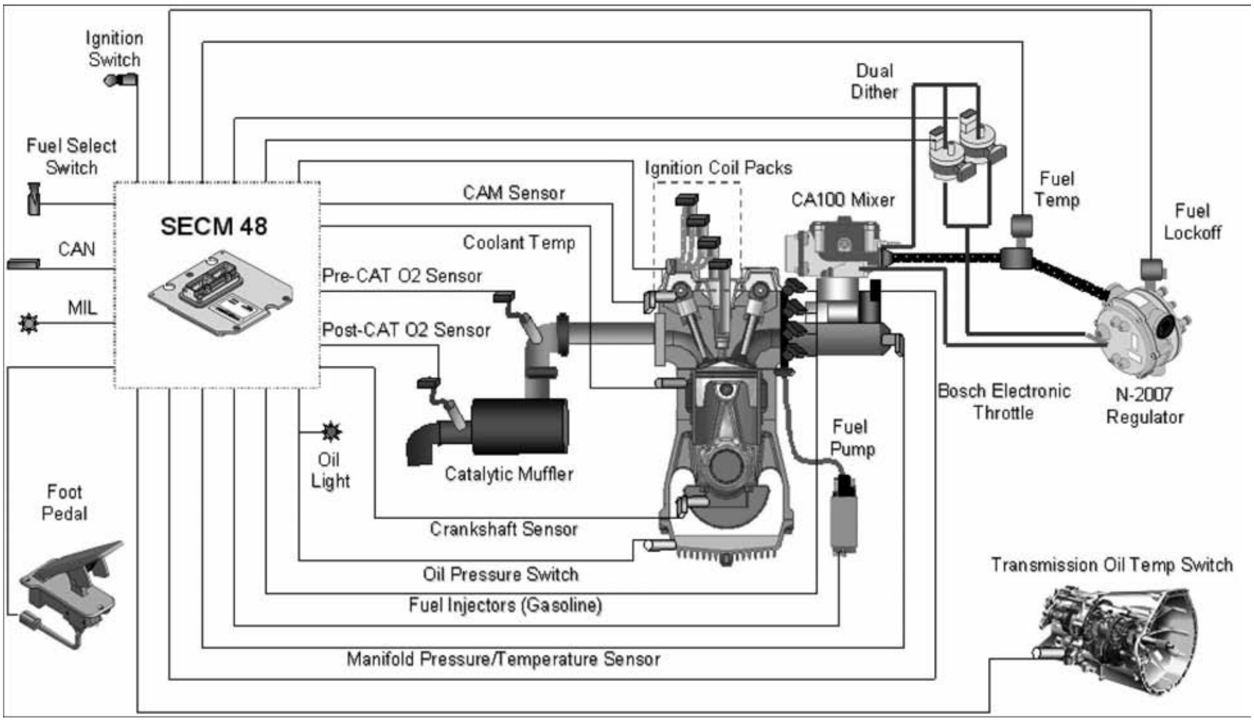
G420FE EMS (Engine Management System) Overview

General Description

MI-07 control system provides a complete, fully integrated engine management system that meets or exceeds 2007 emission standards for Large Spark Ignited (LSI) engines established by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA).

The control system is applicable to naturally aspirated engines running on LPG and/or gasoline. It provides accurate, reliable, and durable control of fuel, spark, and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

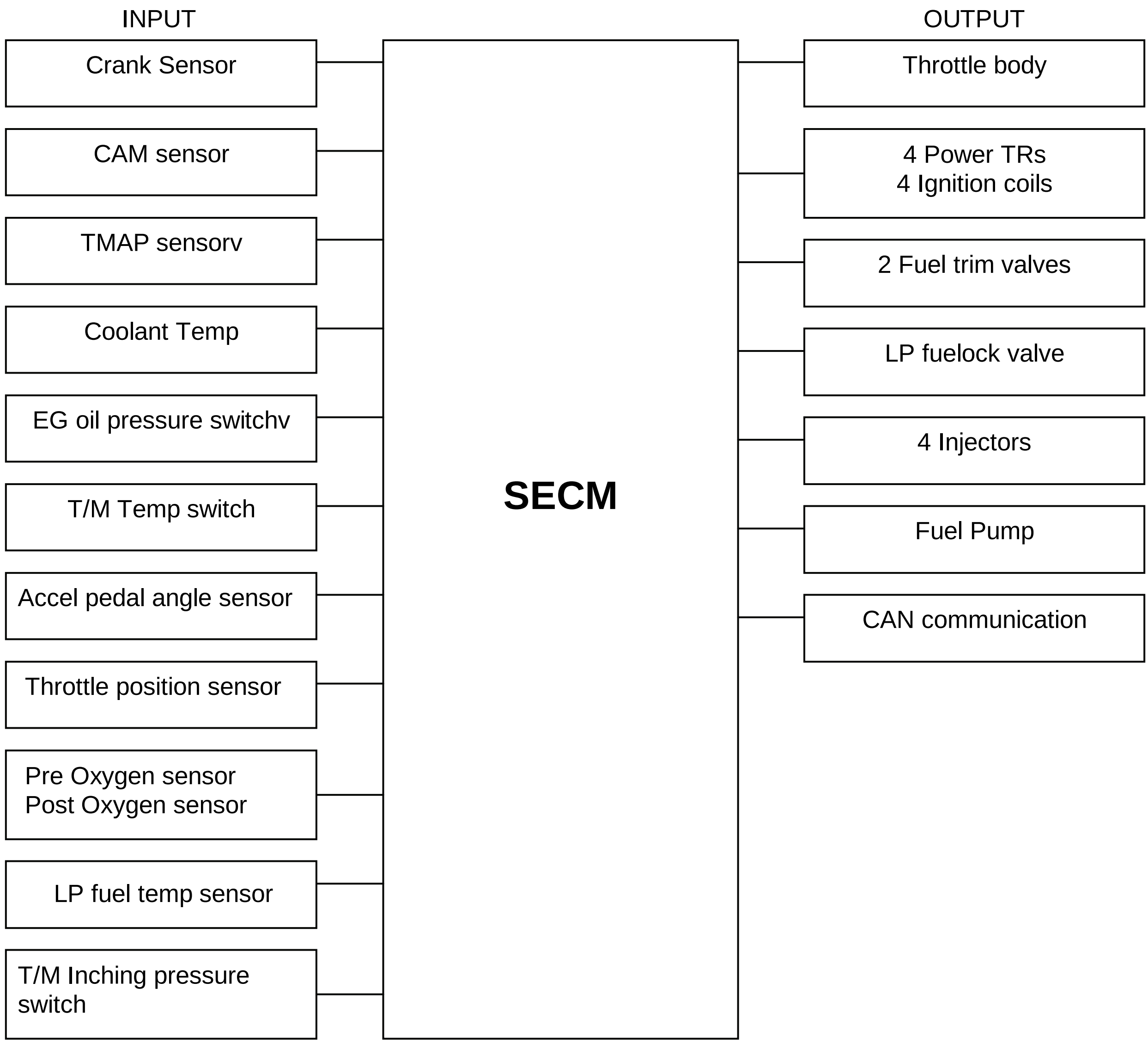
MI-07 is a closed loop system utilizing a catalytic muffler to reduce the emission level in the exhaust gas. In order to obtain maximum effect from the catalyst, an accurate control of the air fuel ratio is required. A small engine control module (SECM) uses two heated exhaust gas oxygen sensors (HEGO) in the exhaust system to monitor exhaust gas content. One HEGO is installed in front of the catalytic muffler and one is installed after the catalytic muffler.



[Figure 1] MI-07 Dual Fuel System for G420FE Engine on Certified Systems

The SECM makes any necessary corrections to the air fuel ratio by controlling the inlet fuel pressure to the air/fuel mixer by modulating the dual fuel trim valves (FTV) connected to the regulator. Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air/fuel mixture. To calculate any necessary corrections to the air fuel ratio, the SECM uses a number of different sensors to gain information about the engine's performance. Engine speed is monitored by the SECM through a Hall Effect sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-07 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM. The SECM controller has full adaptive learning capabilities, allowing it to adapt control function as operating conditions change. Factors such as ambient temperature, fuel variations, ignition component wear, clogged air filter, and other operating variables are compensated.

Dual Fuel System of G420FE (certified engine system)



A dual fuel system operates on either LPG or gasoline. The fuel type can be switched while the engine is stopped or running at low speeds and low loads. The fuel selection switch is a three-position type where the center position is fuel off.

MPI (multi-point injection) system is used for G420FE dual fuel engine and G420F gasoline/dual fuel engine. On gasoline, the camshaft sensor along with the crankshaft sensor is used to control the fuel injectors and feedback from oxygen sensor is used by the SECM to adjust the gasoline delivery based on the exhaust emissions.

MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

• Fuel delivery system
• Spark-ignition control system
• Air throttle
• Sensors/Switches/Speed inputs

The chart below lists the MI-07 components required for a G420F (E) engine operating on LP fuel.

Q'ty		DESCRIPTION
G420FE	**G420F-LP**	
1	1	Engine Control Module (SECM 48-pin)
1	1	Camshaft Position Sensor
1	1	Crankshaft Position Sensor
1	1	TMAP Sensor
1	None	Fuel Temperature Sensor
1	1	Transmission Oil Temperature Switch
2	None	Oxygen Sensors
1	1	Coolant Temperature Sensor
1	1	Engine Oil Pressure Switch
2	None	Fuel Trim Valve
4	4	Ignition Coils
4	4	Power TR
1	1	Fuel Lock Off Solenoid
N-2007	N-2001	LP Regulator
CA-100 (Certified)	CA-100	LP Mixer
1	1	Electronic Throttle Body

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

• Engine/Combustion chamber design
• Intake/Exhaust valve configuration, timing and lift
• Intake/Exhaust manifold design
• Catalytic converter and exhaust system
• Throttle body
• Air intake and air filter
• LPG mixer
• LPG pressure regulator
• Fuel trim valves
• Fuel trim orifices
• Small engine control module (SECM), firmware and calibration †
• Fuel system sensors and actuators
• Ignition system including spark plugs, cables, coils and drivers
• Gasoline injectors and fuel pressure regulator (dual-fuel systems only)

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

• Closed-loop fuel control with fuel specific controls for LPG, and gasoline (MPI) fuels
• Speed-load spark control with tables for dwell, timing, and fuel type
• Speed-load throttle control with table for maximum TPS limiting
• Closed-loop fuel control with two oxygen sensors (one installed pre catalyst and one installed post catalyst). The pre-catalyst oxygen sensor includes adaptive learn to compensate for fuel or component drift. The post-catalyst oxygen sensor includes adaptive learn to compensate the pre-catalyst oxygen sensor setting for pre-catalyst oxygen sensor drift and catalyst aging. The pre-catalyst oxygen sensor function includes parameters for transport delay, O2 set point, excursion rich/lean, jump back rich/lean, and perturbation.
• LPG fuel temperature compensation
• Min/max governing
• All-speed isochronous governing
• Fixed-speed isochronous governing with three switch-selectable speeds
• Fuel enrichment and spark timing modifiers for temperature and fuel type
• Transient fuel enrichment based on rate of change of TPS
• Transient wall wetting compensation for gasoline
• Input sensor selection and calibration
• Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
• CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance

Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics

MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode

The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool

A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

- Fuel filter
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Two orificed fuel trim valves
- Gas/Air mixer with fixed orifice for trim system and fuel temperature sensor
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer.

Dual Dither Valve

The key to meeting emissions requirements when operating in LPG is the dual dither valve hardware in the fuel system. Similar to the MI-04 system, the dual dither system modulates the fuel pressure regulator outlet pressure by providing an offset to the regulator secondary stage reference pressure. By adding a second dither valve, or fuel trim valve (FTV), to the MI-07 system, smoother, more accurate control of supply pressure is achieved, resulting in better control of air fuel ratio and emissions. This smoother control also minimizes wear on fuel system components such as the regulator diaphragm and lever by significantly reducing the pressure pulsations observed with a single FTV.

Regulator Pressure Offset

Regulator pressure offset is achieved through the use of a fixed orifice and a variable orifice in series. The inlet to the fixed orifice is connected to the mixer inlet pressure (roughly equal to ambient pressure). The outlet of the fixed orifice is connected to both the pressure regulator reference port and the inlet to the two FTVs (the variable orifice) that act in parallel. The outlets of the FTVs are connected to the mixer outlet, referred to as Air Valve Vacuum (AVV). Thus, by modulating the FTVs, the pressure regulator reference pressure can be varied between mixer inlet pressure and AVV. For a given change in the pressure regulator reference pressure, the

pressure regulator outlet pressure changes by the same amount and in the same direction. The end result is that a change in FTV modulation changes the outlet pressure of the regulator/fuel inlet pressure of the mixer, and thus the AFR. A major benefit of this trim system results from the use of mixer inlet pressure and AVV as the reference pressure extremes. The pressure differential across the mixer fuel valve is related to these same two pressures, and thus so is fuel flow. Given this arrangement, the bias pressure delta scales with the fuel cone delta pressure. The result is that the trim system control authority and resolution on AFR stays relatively constant for the entire speed and load range of the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve and the FTVs. The lock-off solenoid is energized when fueling with LPG and the engine is turning. FTV modulation frequency will be varied as a function of rpm by the SECM in order to avoid resonance phenomena in the fuel system. FTV commands will be altered by the SECM in order to maintain a stoichiometric air-fuel ratio. Commands are based primarily on feedback from the exhaust gas oxygen sensor, with an offset for fuel temperature.

MI-07 LP Fuel Filter

After exiting the fuel tank, liquid propane passes through a serviceable inline fuel filter to the electric fuel lock off. Figure 3 shows a typical inline type LP fuel filter manufactured by Century. The primary function of the fuel filter is to remove particles and sediments that have found their way into the tank. The LP fuel filter will not remove heavy end solids and paraffins that build up in LPG fuel systems as a result of vaporization.

Figure 3. Inline LP Fuel Filter

MI-07 Fuel Lock-Off (Electric)

The fuel lock-off is a safety shutoff valve, normally held closed by spring pressure, which is operated by an electric solenoid and prevents fuel flow to the regulator/ converter when the engine is not in operation. This is the first of three safety locks in the MI-07 system.

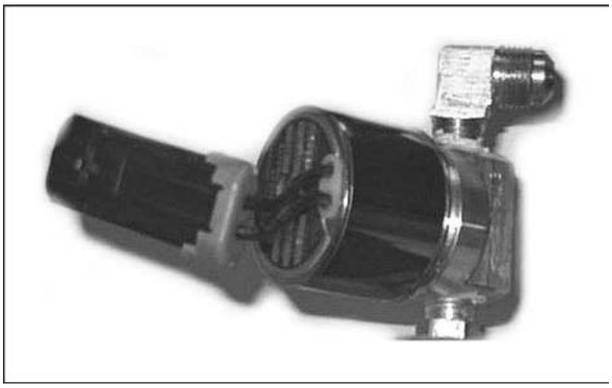


Figure 4. Electric Fuel Lock Assembly

In the MI-07 design, power is supplied to the fuel lock-off via the main power relay with the SECM controlling the lock-off ground (earth) connection. The lock-off remains in a normally closed (NC) position until the key switch is activated.
This supplies power to the lock-off and the SECM, but will not open the lock-off via the main power relay until the SECM provides the lock-off ground connection. This design gives the SECM full control of the lock-off while providing additional safety by closing the fuel lock-off in the unlikely event of a power failure, wiring failure or module failure.

When the liquid service valve in the fuel container is opened, liquid propane flows through the LP filter and through the service line to the fuel lock-off. Liquid propane enters the lock-off through the 1/4" NPT liquid inlet port and stops with the lock-off in the normally closed position. When the engine is cranked over the main power relay applies power to the lock-off and the SECM provides the lock-off ground causing current to flow through the windings of the solenoid creating a magnetic field. The strength of this magnetic field is sufficient to lift the lock-off valve off of its seat against spring pressure. When the valve is open liquid propane, at tank pressure, flows through the lock-off outlet to the pressure regulator/converter. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: Crank, when the crankshaft position sensor detects any engine revolutions; Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions; and the Run state, when the engine reaches pre-idle rpm.

When an operator turns on the key switch the lock-off is opened, but if the operator fails to crank the engine the SECM will close the lock-off after 5 seconds.

N-2007 Pressure Regulator/Vaporizer

The pressure regulator/vaporizer receives liquid LPG from the fuel storage tank, drops the pressure, changes the LPG phase from liquid to vapor, and provides vapor phase LPG at a regulated outlet pressure to the mixer. To offset the refrigeration effect of the vaporization process, the regulator will be supplied with engine coolant flow sufficient to offset the latent heat of vaporization of the LPG. A thermostat provided in the coolant supply line to maintain regulator outlet coolant temperature at or below 140oF (60°C) will minimize the deposit of fuel contaminants and heavy ends in the regulator and assure a more controlled vaporization process with reduced pressure pulsations.

A higher flow pressure regulator is required on larger engines.

Figure 5. N-2007 Regulator

The regulator is normally closed, requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2007 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced, the liquid propane vaporizes and refrigeration occurs inside the regulator due to the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber.

N-2007 Operation

(Refer to Figure 6.)
Liquid propane, at tank pressure, enters the N-2007 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psig (10.342 kPa) it causes a pressure/force imbalance across the primary diaphragm (8). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

Since the fuel pressure has been reduced from tank pressure to 1.5 psig (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve, a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator, which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

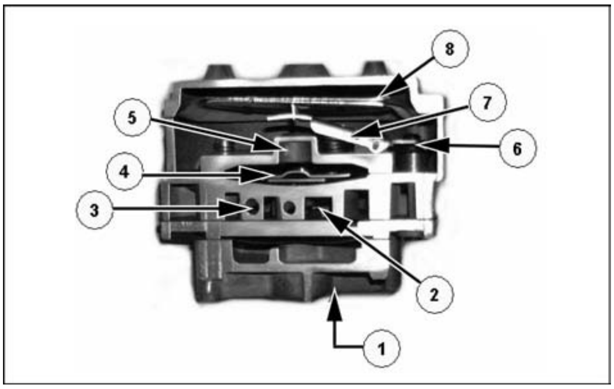


Figure 6. Parts View of N-2007 Regulator

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

The mixer fuel inlet is fitted with a thermistor-type temperature sensor. This permits the SECM to correct fuel pressure to compensate for variations in fuel temperature. Left uncorrected, fuel temperature variations can cause significant variations in air fuel ratio.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.


Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2007 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.


Figure 8. CA100 Mixer Attached to Throttle Body

(Refer to Figure 98.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5)

and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

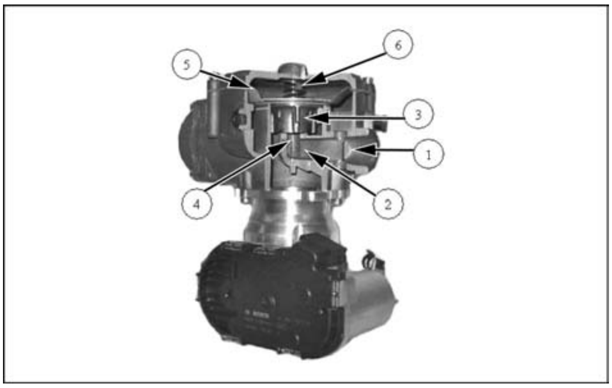


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

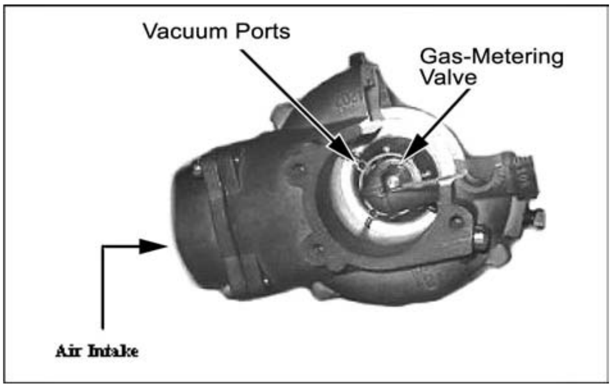


Figure 10. Bottom View of Air Valve Assembly


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.

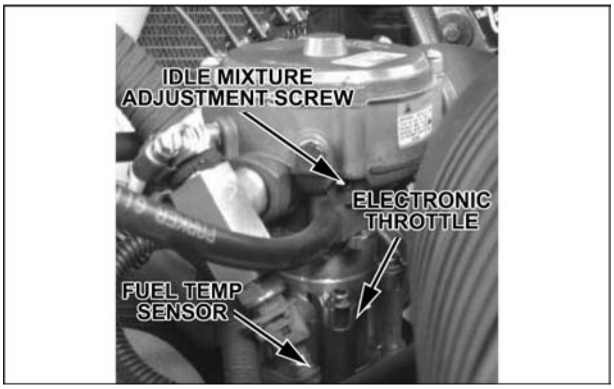


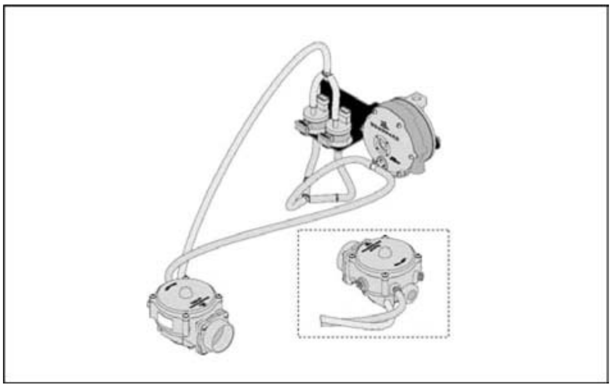
Figure 12. Idle Mixture Adjustment Screw
(with tamper proof cap removed)

Fuel Trim Valve (FTV)

The Fuel Trim Valve (FTV) is a two-way electric solenoid valve and is controlled by a pulse-width modulated (PWM) signal provided by the SECM. Two FTVs are used to bias the output fuel pressure on the LPG regulator/converter (N-2007), by metering air valve vacuum (AVV) into the atmospheric side of the N-2007 secondary regulator diaphragm. An orifice balance line connected to the air inlet side of the mixer provides atmospheric reference to the N-2007 when the FTV is closed. The SECM uses feedback voltage from the O2 sensor to determine the amount of bias needed to the regulator/converter.

In normal operation the N-2007 maintains fuel flow at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing from the N-2007 will vary depending on how far the secondary diaphragm opens the secondary valve in response to the negative pressure signal generated by the air/fuel mixer. One side of the N-2007 secondary diaphragm is referenced to FTV control pressure while the other side of the diaphragm reacts to the negative pressure signal from the mixer. If the pressure on the reference side of the N-2007 secondary diaphragm is reduced, the diaphragm will close the secondary valve until a balance condition exists across the diaphragm, reducing fuel flow and leaning the air/fuel mixture.

Branch-Tee Fitting



A branch-tee fitting is installed in the atmospheric vent port of the N-2007 with one side of the branch-tee connected to the intake side of the mixer forming the balance line and referencing atmospheric pressure. The other side of the branch-tee fitting connects to the FTV inlet (small housing side). The FTV outlet (large housing connector side) connects to the AVV port. When the FTVs are open AVV is sent to the atmospheric side of the N-2007 secondary diaphragm, which lowers the reference pressure, closing the N-2007 secondary valve and leaning the air/fuel mixture. The MI-07 system is calibrated to run rich without the FTV. By modulating (pulsing) the FTVs the SECM can control the amount of AVV applied to the N-2007 secondary diaphragm. Increasing the amount of time the FTVs remain open (modulation or duty cycle) causes the air/fuel mixture to become leaner; decreasing the modulation (duty cycle) enriches the mixture.

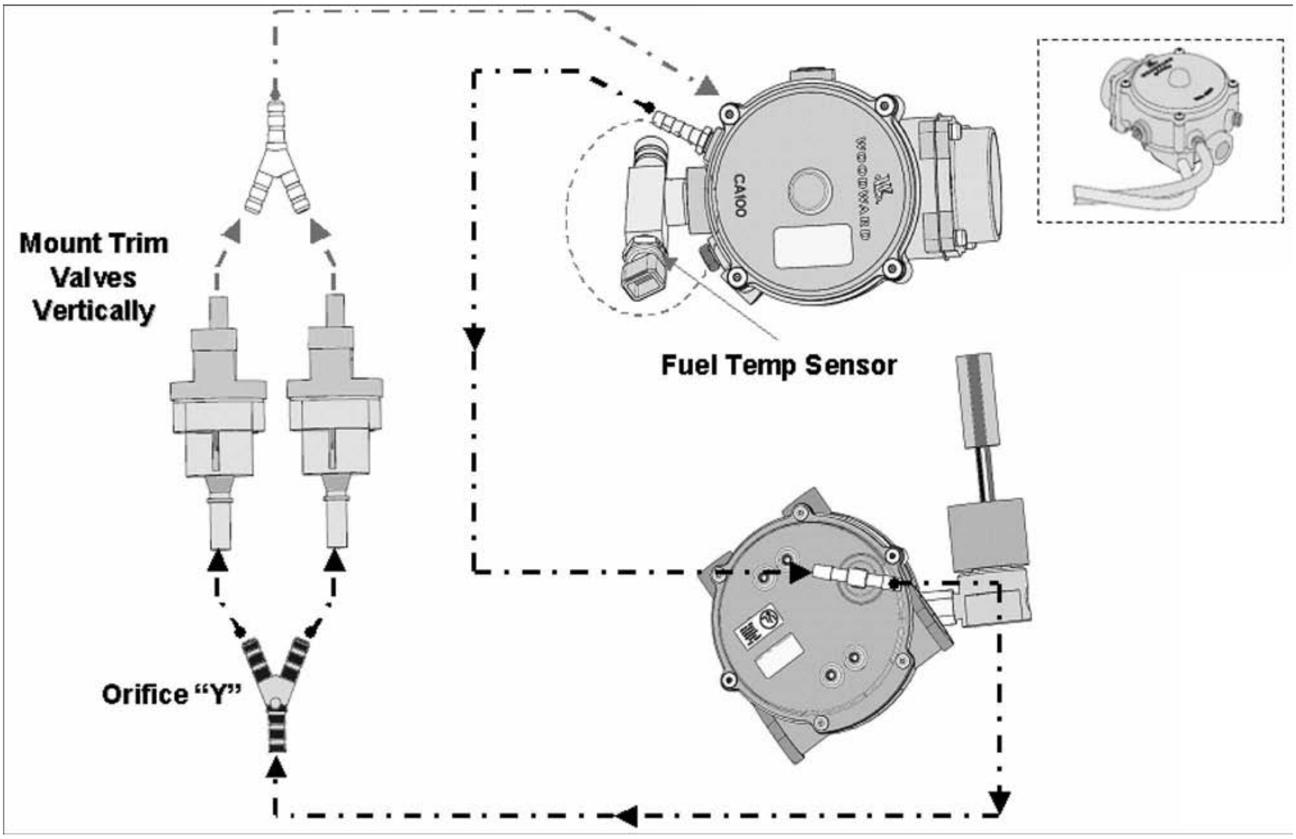
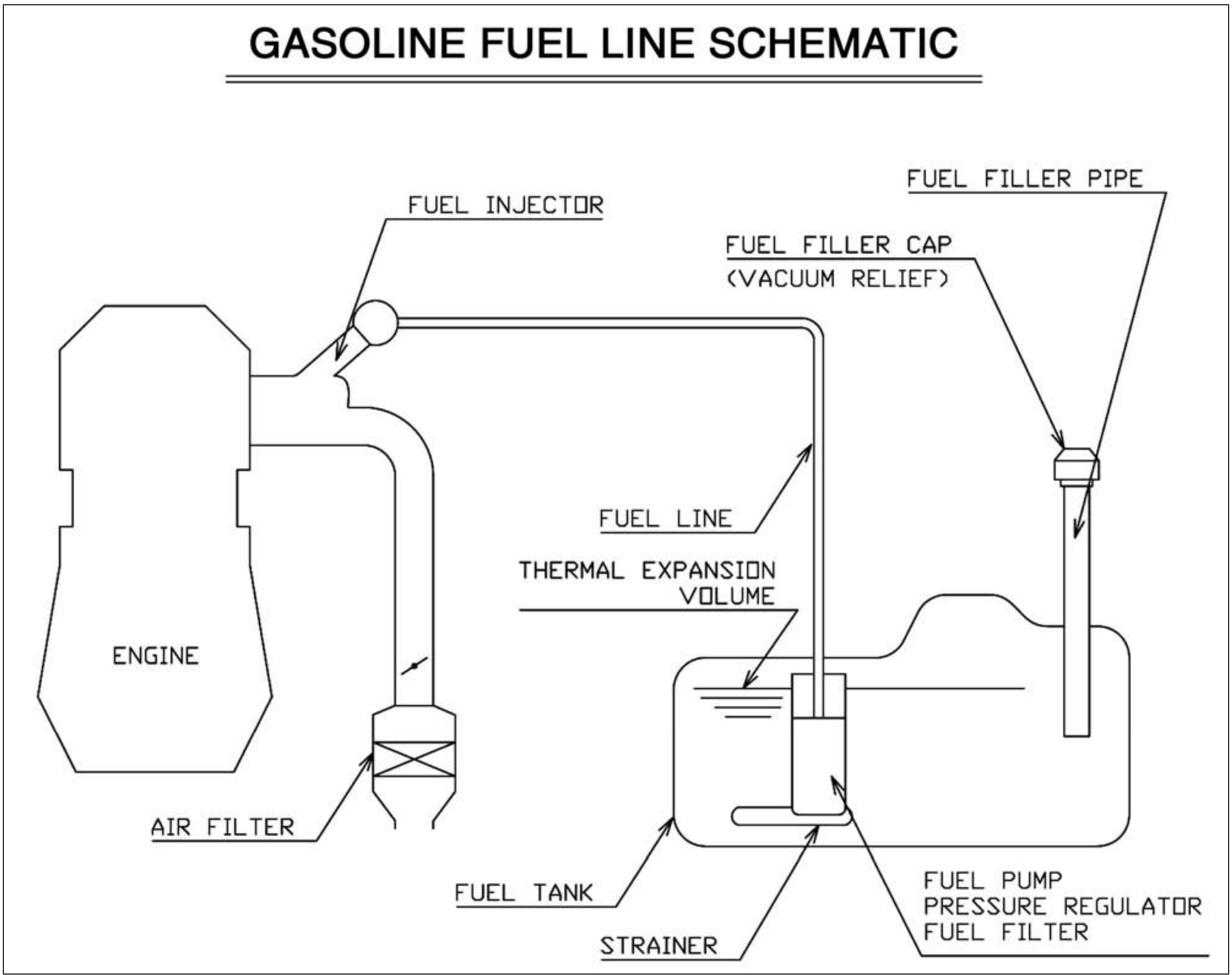


Figure 13. Fuel Trim Valves Connected to MI-07 System

MPI Gasoline System Operation

MPI (multi-point injection) system is used for G420FE dual fuel engine and G420F gasoline/dual fuel engine. An electric fuel pump in gasoline fuel tank supplies the fuel and generates the injection pressure. The gasoline fuel pressure regulator is a one-way, non-return configuration. All gasoline specific components are automotive production parts and validated to strict automotive standards. Four (4) sequential injection channels are supported. Injector as an electronic controlled fuel injection unit, is solenoid valve which supplies exactly calculated fuel as a spray to engine to best combustion under the condition of various engine load and speed.

For fuel consumption reduction, engine performance enhancement and emission reduction, ECM controls fuel injection to satisfy air fuel ratio required by system by reflecting induced airflow and air fuel ratio among emission and adjusting injector operating time. To enhance these control characteristics, quick response of injector is required, and spray feature of injector is important for perfect combustion.



Use of unleaded gasoline of 87 octane or higher is recommended for optimal performance of the MI-07 system.

A gasoline fuel system includes the following components:
Gasoline fuel pump
Fuel filter
Pressure regulator
Fuel rail
Fuel injectors
Small engine control module (SECM) and related sensors and equipment

Electronic Throttle System

The electronic throttle system controls engine output (speed and torque) through electronic control of mass airflow to the engine. Any DC motor-actuated or Limited Angle Torquemotor (LAT)-actuated throttle with less than 5A peak and 2A steady state can be controlled. The TPS must be directly coupled to the throttle shaft for direct shaft position measurement.

A commonly used throttle is the Bosch DV-E5. This throttle is available in a variety of bore sizes to meet specific engine needs: 32mm, 40mm, and 54mm are readily available throttle bore sizes; other sizes are possible. The Bosch throttle is a fully validated automotive component incorporating a brushed DC motor with gear reduction, dual throttle position sensors, throttle plate, and cast aluminum housing. In the event of an electrical disconnection or other related failure, the throttle plate returns to a limp-home idle position at a no-load engine speed above curb idle speed. This provides sufficient airflow for the engine to move the vehicle on level ground. Any throttle bodies used for MI-07 meet or exceed the specification for the Bosch throttle bodies.

In terms of response, the throttle is capable of fully opening and closing in less than 50 msec. Position resolution and steady state control should be 0.25% of full travel or better.

MI-07 Electronic Throttle

Conventional throttle systems rely on a mechanical linkage to control the throttle valve. To meet fluctuating engine demands a conventional system will typically include a throttle valve actuator designed to readjust the throttle opening in response to engine demand, together with an idle control actuator or idle air bypass valve.

In contrast, the MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm or 40mm electronic throttle body DV-E5 (Figure 14). The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

Figure 14. Bosch Electronic Throttle Body

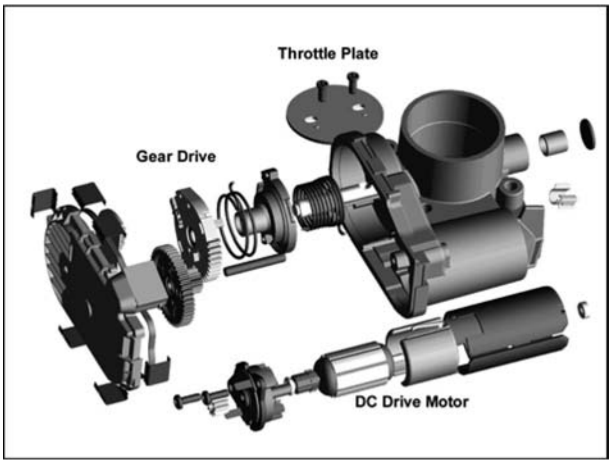
The MI-07 uses a dual TPS design (TPS1 and TPS2). The SECM continuously checks and monitors all sensors and calculations that effect throttle valve position whenever the engine is running. If any malfunctions are encountered, the SECM's initial response is to revert to redundant sensors and calculated data. If no redundant signal is available or calculated data cannot solve the malfunction, the SECM will drive the system into one of its limp-home modes or shut the engine down, storing the appropriate fault information in the SECM.

There are multiple limp-home modes available with electronic throttle control:

1. If the throttle itself is suspected of being inoperable, the SECM will remove the power to the throttle motor. When the power is removed, the throttle blade returns to its "default" position, approximately 7% open.

2. If the SECM can still control the throttle but some other part of the system is suspected of failure, the SECM will enter a "Reduced Power" mode. In this mode, the power output of the engine is limited by reducing the maximum throttle position allowed.

3. In some cases, the SECM will shut the engine down. This is accomplished by stopping ignition, turning off the fuel, and disabling the throttle.



Picture courtesy of Robert Bosch GmbH

Figure 15. Throttle Body Assembly Exploded View

Ignition System

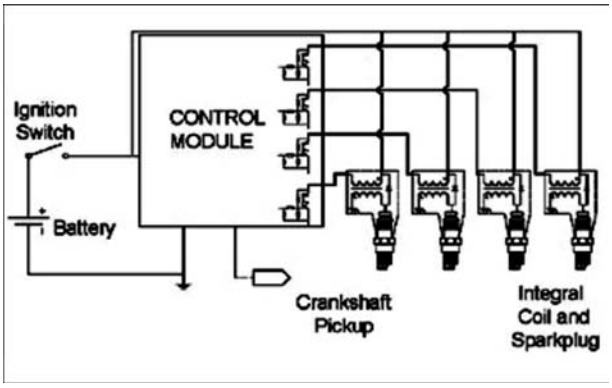
Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

• SECM
• Ignition coil drivers *
• Ignition coil(s) *
• Crankshaft position sensor *
• Crankshaft timing wheel *
• Cam position sensor *
  (for sequential ignition or fuel injection only)
• Cam timing wheel *
  (for sequential ignition or fuel injection only)
• Spark plugs *

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

Coil-On-Plug (Coil Pack) Ignition System

Coil-on-plug (COP) is a type of distributorless ignition system where individual ignition coils are mounted directly over each spark plug. No spark plug wires are used. On most engines, the plugs and coils are located on top of the cylinder head for easy mounting of the coils. A topside location is best because it keeps the coils away from the heat of the exhaust.



COP Components

In a typical COP ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to determine firing order and turn the individual ignition coils on and off.

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

The primary difference between COP and other ignition systems is that each COP coil is mounted directly atop the spark plug so the voltage goes directly to the plug electrodes without having to pass through a distributor or wires. It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).

Misfires

COP problems can include many of the same ailments as other ignition systems such as misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM can kill an individual coil and prevent that cylinder from firing. But with COP, an individual coil failure will only cause misfiring in one cylinder.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, even contaminated fuel. These other possibilities should all be ruled out before a COP unit is replaced.

A COP engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

Exhaust System

Heated Exhaust Gas Oxygen Sensors (HEGO)

The MI-07 system utilizes two HEGO (O2) sensors. One sensor is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O2 sensor feedback, the MI-07 system supplies a stoichiometric air-fuel ratio to the catalytic converter. The catalytic converter then reduces emissions to the required levels. The second sensor is a post-catalyst sensor that detects the amount of oxygen after the catalyst. This sensor is used as a secondary control point to adjust the pre-catalyst setpoint to ensure proper catalyst conversion efficiency.

Figure 18. HEGO (O2) Sensor

Once a HEGO sensor reaches approximately 600°F (316°C), it becomes electrically active. The concentration of oxygen in the exhaust stream determines the voltage produced. If the engine is running rich, little oxygen will be present in the exhaust and voltage output will be relatively high. Conversely, in a lean situation, more oxygen will be present and a smaller electrical potential will be noticed.

In order for the sensor to become active and create an electrical signal below 600°F (316°C) a heated element is added to the sensor housing. Two wires provide the necessary 12 Vdc and ground signal for the heater element. A fourth wire provides an independent ground for the sensor. The pre-catalyst sensor heater is powered by the main power relay and is always powered. The post-catalyst sensor heater is powered from an additional relay that is controlled by the SECM. This relay is only energized when the SECM calculates that water condensation in the exhaust system and catalytic muffler prior to the sensor should be evaporated. This is to avoid thermal shock of the sensor that could prematurely fail the sensor.

The HEGO stoichiometric air-fuel ratio voltage target is approximately 500 mV and changes slightly as a function of speed and load. When the pre-catalyst HEGO sensor sends a voltage signal less than 450 mV the SECM interprets the air-fuel mixture as lean. The SECM then decreases the PWM duty cycle sent to the fuel trim valves in order to increase the fuel pressure to the mixer inlet; thus richening air-fuel mixture. The opposite is true if the SECM receives a voltage signal above 450 mV from the HEGO. The air-fuel mixture would then be interpreted as being too rich and the SECM would increase the duty cycle of the trim valves.

⚠ CAUTION

The HEGO sensors are calibrated to work with the MI-07 control system. Use of alternate sensors may impact performance and the ability of the system to diagnose rich and lean conditions.

Catalytic Muffler

In order to meet 2007 emission requirements a 3-way catalyst is necessary.

All exhaust gases pass through a catalyst that is mounted in the catalytic muffler. It filters the harmful gases through a dense honeycomb structure coated with precious metals such as platinum, palladium, and rhodium. Chemical reactions occur on these surfaces to convert the pollutants into less harmful gases. Catalysts store oxygen on lean mixtures (less than optimal amount of fuel) and release oxygen on rich mixtures (more than optimal amount of fuel). The primary pollutant produced on the lean swing is nitrous oxide. Oxygen is removed from nitrous oxide by the converter, resulting in nitrogen gas, a harmless emission. On the rich cycle, the primary pollutant is carbon monoxide. By adding the oxygen that was stored on the lean cycle to the carbon monoxide, carbon dioxide is produced.

Inside the catalytic muffler is a three-way catalyst as well as sound dampening and spark arresting features. The three-way catalyst section consists of a honeycomb coated with a mixture of platinum, palladium and rhodium. As engine exhaust gases flow through the converter passageways, they contact the coated surface, which initiate the catalytic process. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. Cerium is also used to promote oxygen storage and improve oxidation efficiency.

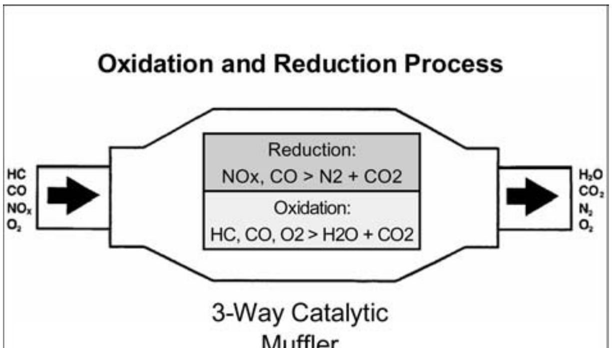
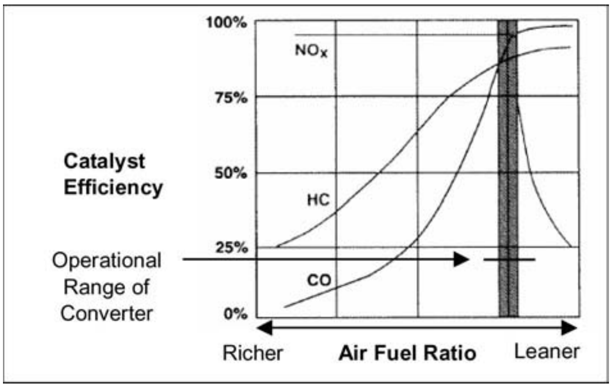


Figure 25

As exhaust and catalyst temperatures rise the following reaction occurs:

- Oxides of nitrogen (NOx) are reduced into simple nitrogen (N2) and carbon dioxide (CO2).
- Hydrocarbons (HC) and carbon monoxide (CO) are oxidized to create water (H2O) and carbon dioxide (CO2).



The MI-07 control system monitors the exhaust stream pre and post catalyst and uses this information to control the air-fuel mixture. By using the signals from the HEGOs, the SECM can increase or decrease the amount of oxygen in the exhaust by modulating the FTVs and adjusting the air-fuel ratio. This control scheme allows the SECM to make sure that the engine is running at the correct air to fuel ratio so that the catalyst can perform as required to meet the emissions certification.

SECM

General Description

The Small Engine Control Module (SECM) controller has full authority over spark, fuel and air. Utilizing a Freescale micro controller, the SECM has 48 pins of I/O and is fully waterproof and shock hardened. To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in three main categories:

• Fuel Management
• Load/Speed Management
• Ignition Management

The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the MI-07 Service Tool software through a CAN (Controller Area Network) communication link.

Constant battery power (12 Vdc) is supplied through the fuse block to the SECM and the main power relays. Upon detecting a key-switch ON input, the SECM will fully power up and energize the main power relays.
The energized main power relays supply 12 Vdc power to the heated element of the oxygen sensors, fuel lock-off, fuel trim valves (FTVs), gasoline injectors, gasoline fuel pump, crank sensor, cam sensor, and the ignition coils.
The SECM supplies voltage to the electronic throttle actuator, oil pressure switch, fuel temperature sensor, and the coolant temperature sensor.
Transducer or sensor power (+ 5 Vdc) is regulated by the SECM and supplied to the manifold temperature/air pressure (TMAP) sensor, throttle position sensor (TPS), and the accelerator pedal position sensors (APP1 & APP2).

The SECM provides a transducer ground for all the sensors, and a low side driver signal controlling the fuel lock-off, MIL, gasoline injectors, gasoline fuel pump, and FTVs.

Fuel Management

During engine cranking at startup, the SECM provides a low side driver signal to the fuel lock-off, which opens the lock-off allowing liquid propane to flow to the N-2007 regulator. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: Crank, when the crankshaft position sensor detects any engine revolutions Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions Run state, when the engine reaches pre-idle RPM.

When an operator turns on the key switch the lock-off is opened but if the operator fails to crank the engine, the SECM will close the lock-off after 5 seconds.

To maintain proper exhaust emission levels, the SECM uses a heated exhaust gas oxygen sensor (HEGO) mounted before the catalyst, to measure exhaust gas content in the LP gas system. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor or Hall-Effect type sensor.
Intake manifold air temperature and absolute pressure are monitored with a (TMAP) sensor.
The HEGO voltage is converted to an air/fuel ratio value. This value is then compared to a target value in the SECM. The target value is based on optimizing catalyst efficiency for a given load and speed. The SECM then calculates any corrections that need to be made to the air/fuel ratio.
The system operates in open loop fuel control until the engine has done a certain amount of work.
This ensures that the engine and HEGO are sufficiently warmed up to stay in control. In open loop control, the FTV duty cycle is based on engine speed and load.
Once the HEGO reaches operating temperature the fuel management is in closed loop control for all steady state conditions, from idle through full throttle.
In closed loop mode, the FTV duty cycle is based on feedback from the HEGO sensor. The system may return to open-loop operation when engine load or engine speed vary beyond a chosen threshold.

The SECM makes any necessary corrections to the air-fuel ratio by controlling the inlet fuel pressure to the air-fuel mixer Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air-fuel mixture. Control is achieved by modulating the fuel trim valves.

Speed Management

Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the SECM is electronically connected both to the foot pedal assembly and the throttle body.

The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed.

Figure 19. Foot Pedal

The use of electronic throttle control (ETC) ensures that the engine receives only the correct amount of throttle opening for any given situation, greatly improving idle quality and drivability.

Two throttle position sensors (TPS1 and TPS2), which are integral to the drive-by-wire (DBW) throttle assembly, provide feedback for position control by monitoring the exact position of the throttle valve. See Figure 20.

SECM self-calibration and “cross checking” compares both signals and then checks for errors.

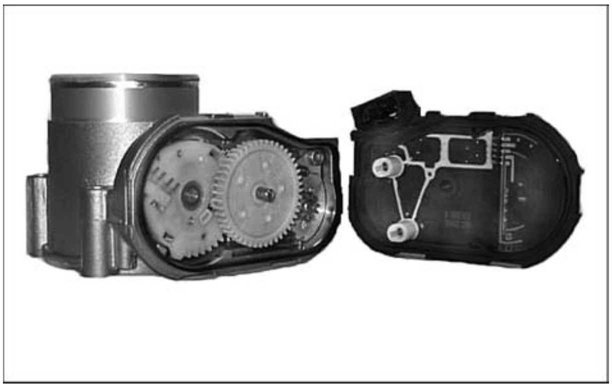


Figure 20. Throttle Position Sensor (TPS) on DV-E5 Throttle

NOTE : The DV-E5 throttle is not a serviceable assembly. If a TPS sensor fails, the assembly should be replaced.

The MI-07 system also performs minimum (min) and maximum (max) speed governing through the SECM and DBW throttle. For min governing, or idle speed control, the idle speed is fixed by the SECM. Unlike a mechanical system, the idle speed is not adjustable by the end user. The idle speed is adjusted by the SECM based on engine coolant temperature. At these low engine speeds, the SECM uses spark and throttle to maintain a constant speed regardless of load.

The MI-07 system eliminates the need for air velocity governors. This substantially increases the peak torque and power available for a given system as shown in Figure 21. When the engine speed reaches the max governing point the speed is controlled by closing the DBW throttle. Using the DBW throttle as the primary engine speed control allows for a smooth transition into and out of the governor. If excessive over speed is detected, the engine is shut down.

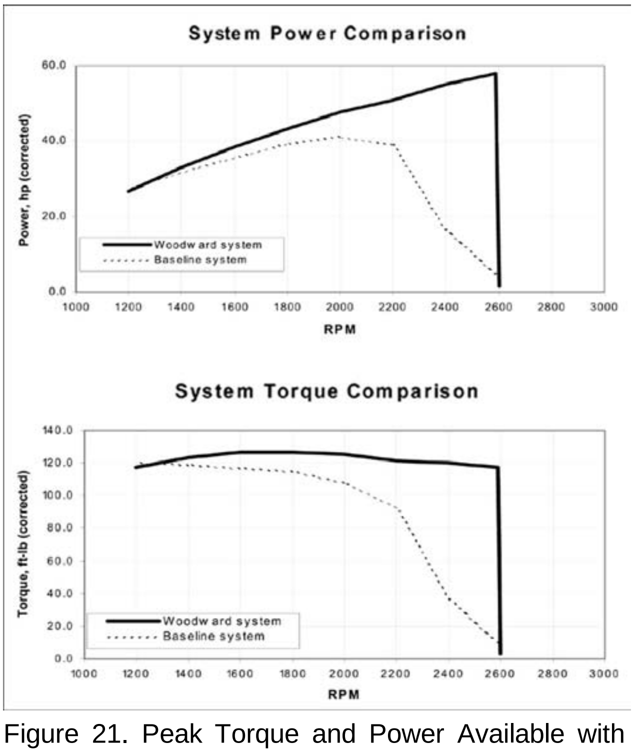


Figure 21. Peak Torque and Power Available with MI-07 System

Drive-By-Wire Signal Flow Process

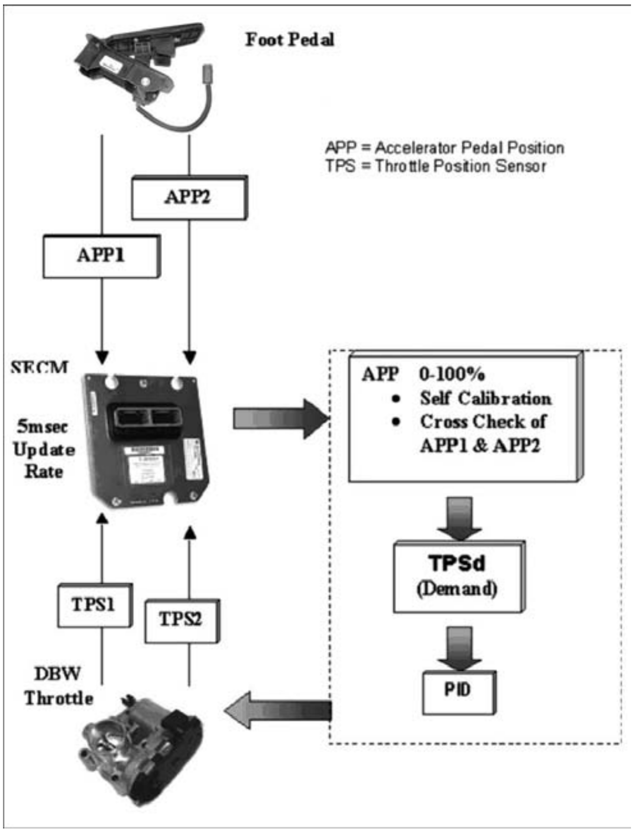


Figure 22. Drive-By-Wire Signal Flow Process

Figure 22 describes the signal flow process of the MI-07 DBW section. The foot pedal assembly uses two potentiometers to detect pedal position.
These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM.
The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly. A demand position for the throttle will then be derived and sent to the throttle as a throttle position sensor demand (TPSd). This signal will be processed through a PID (Proportional, Integral, Derivative) controller in the SECM to achieve the appropriate motor-current response then passed to the throttle. The throttle moves to the commanded position and provides a feedback signal from the throttle position sensors (TPS1 and TPS2) to the SECM.

Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, and idle speed control.

SECM Electrical Mounting

Recommendations

In order to prevent the possibility of any SECM malfunctions due to EMI/RFI emissions, engine packagers and OEMs should follow industry “best practices” and the SECM mounting and harness recommendations listed below:

- The SECM should be mounted in a location that minimizes the amount of EMI the module is exposed to by locating it as far as practical from all high tension components, such as ignition coils, distributors, spark plug wires, etc. It is recommended that the SECM be mounted at least 29.5” (749 mm) away from the distributor and ignition coil, and at least 20” (508 mm) from the nearest plug wire.
- All wiring harnesses should be routed to minimize coupling (both radiated and conducted), and be securely fastened to minimize movement and maintain proper clearance between the SECM and all ignition system components.
- The OEM must ensure that a high-quality ground connection between the SECM and battery negative (–) is provided and can be maintained for the useful life of the vehicle. This may require the use of star-type washers on all ground lug connections between the SECM and the battery and/or special preparation of all mating surfaces that complete the ground connection in order to ensure that the connection is sound.

Engineering judgment must be exercised on all applications to determine if appropriate measures have been implemented to minimize EMI exposure to the SECM and associated cabling. The above recommendations do not provide any guarantee of proper system performance.

SECM Wiring Diagrams for G420FE

⚠ CAUTION—PROPER WIRING

To prevent system faults be sure to follow good wiring practices. Poor wiring may cause unexpected or intermittent failures not related to MI-07 components.

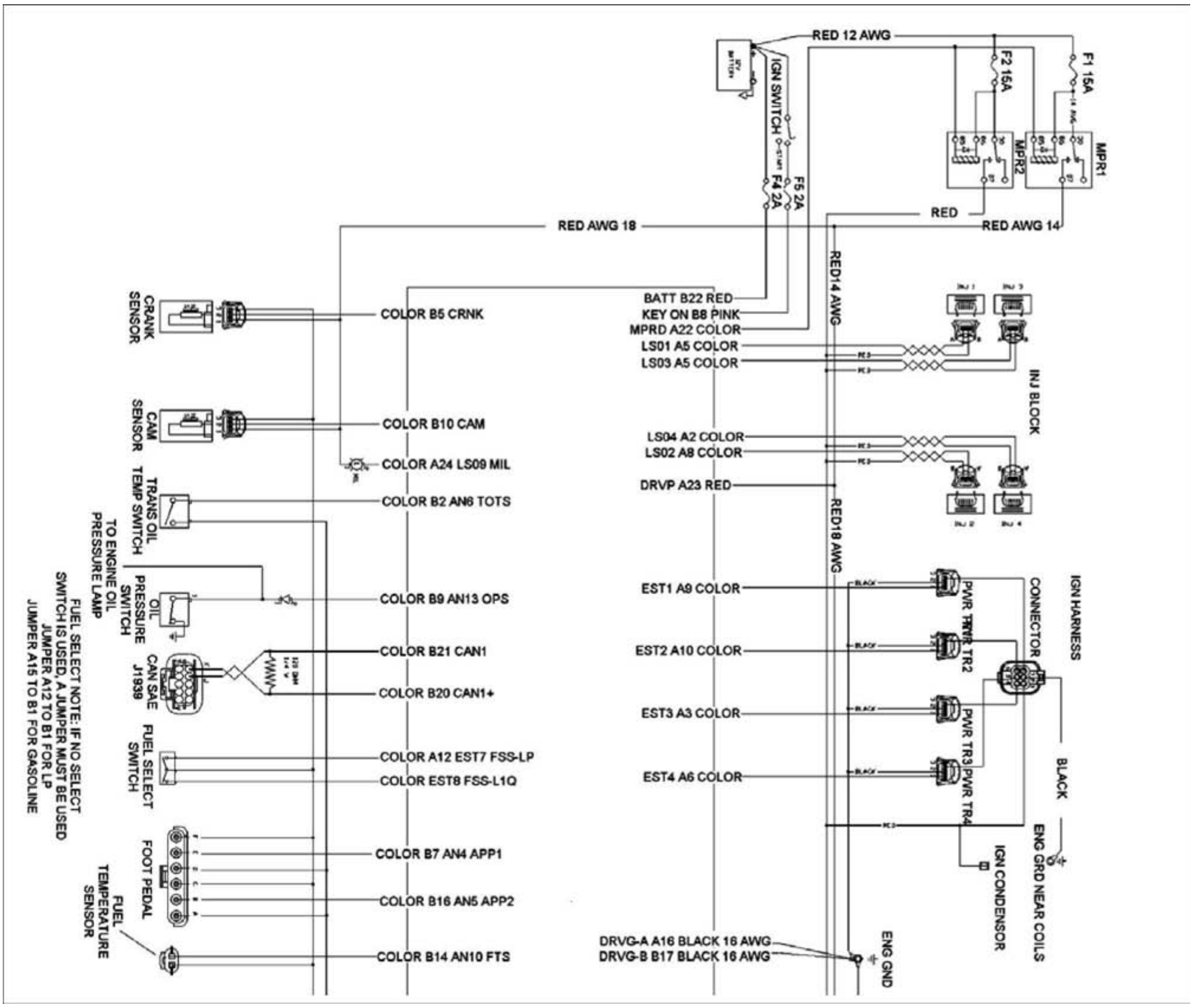


Figure 23. SECM Wiring Diagram for G420FE Engine Systems

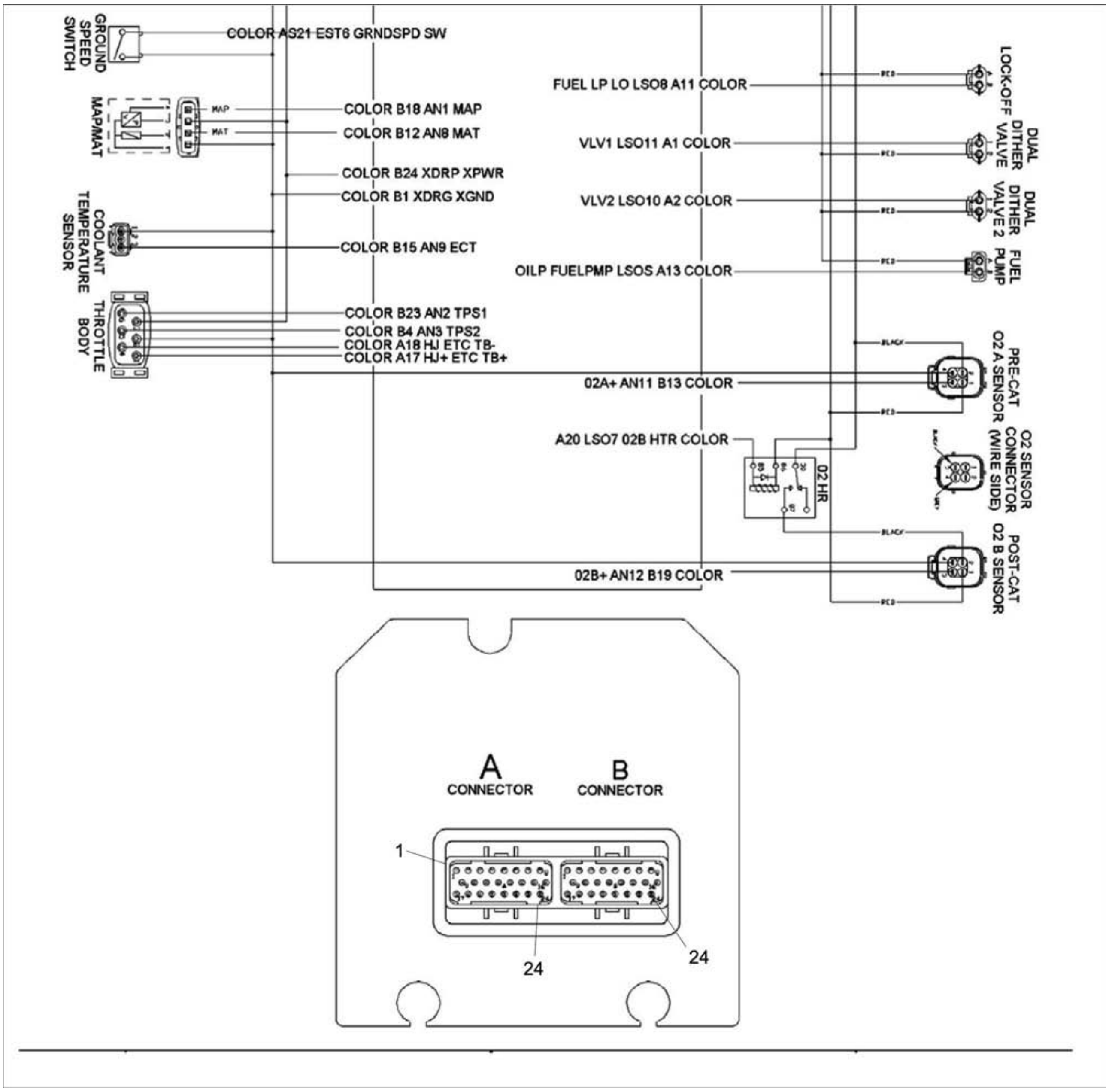


Figure 23. SECM Wiring Diagram for G420FE Engine Systems

G420F EMS (Engine Management System) Overview

General Description

MI-07 control system provides a complete, fully integrated engine management system for naturally aspirated engines.

It provides accurate, reliable, and durable control of spark and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

The SECM monitors the engine through a number of different sensors to ensure optimal performance. Engine speed is monitored by the SECM through a Hall Effect sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-07 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM

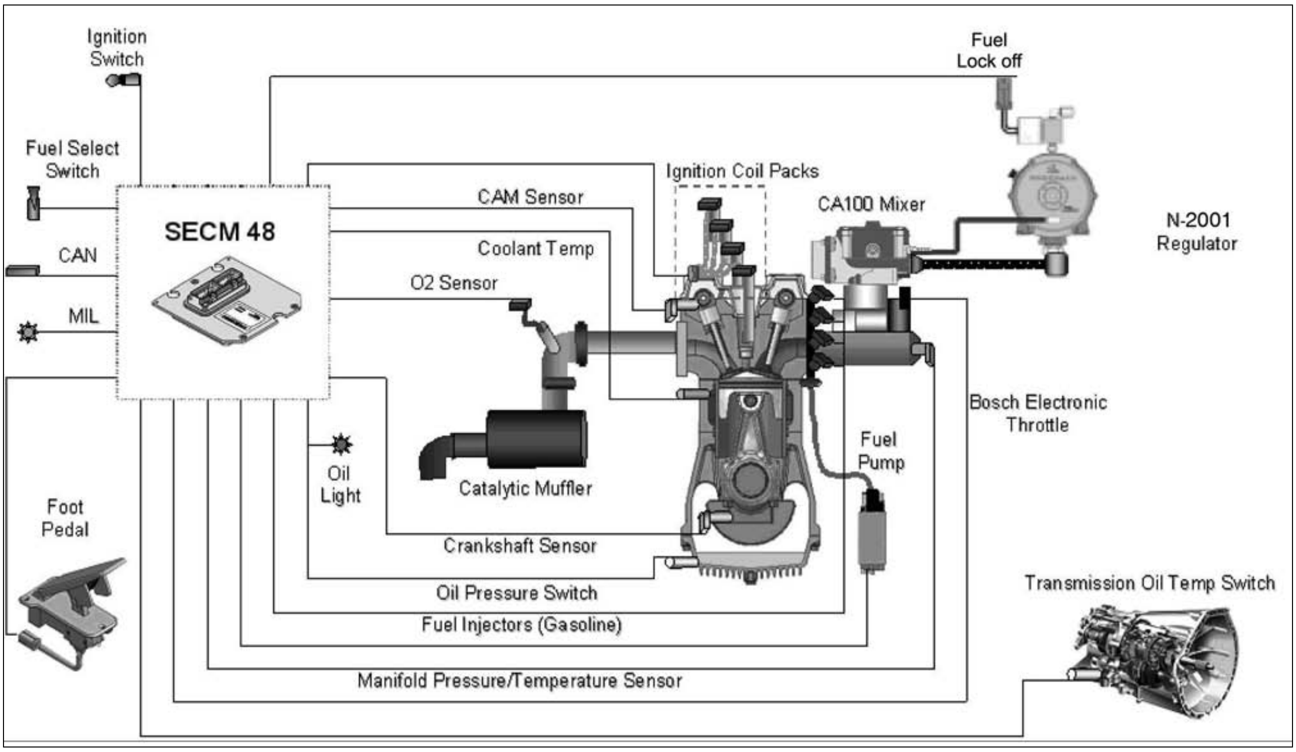
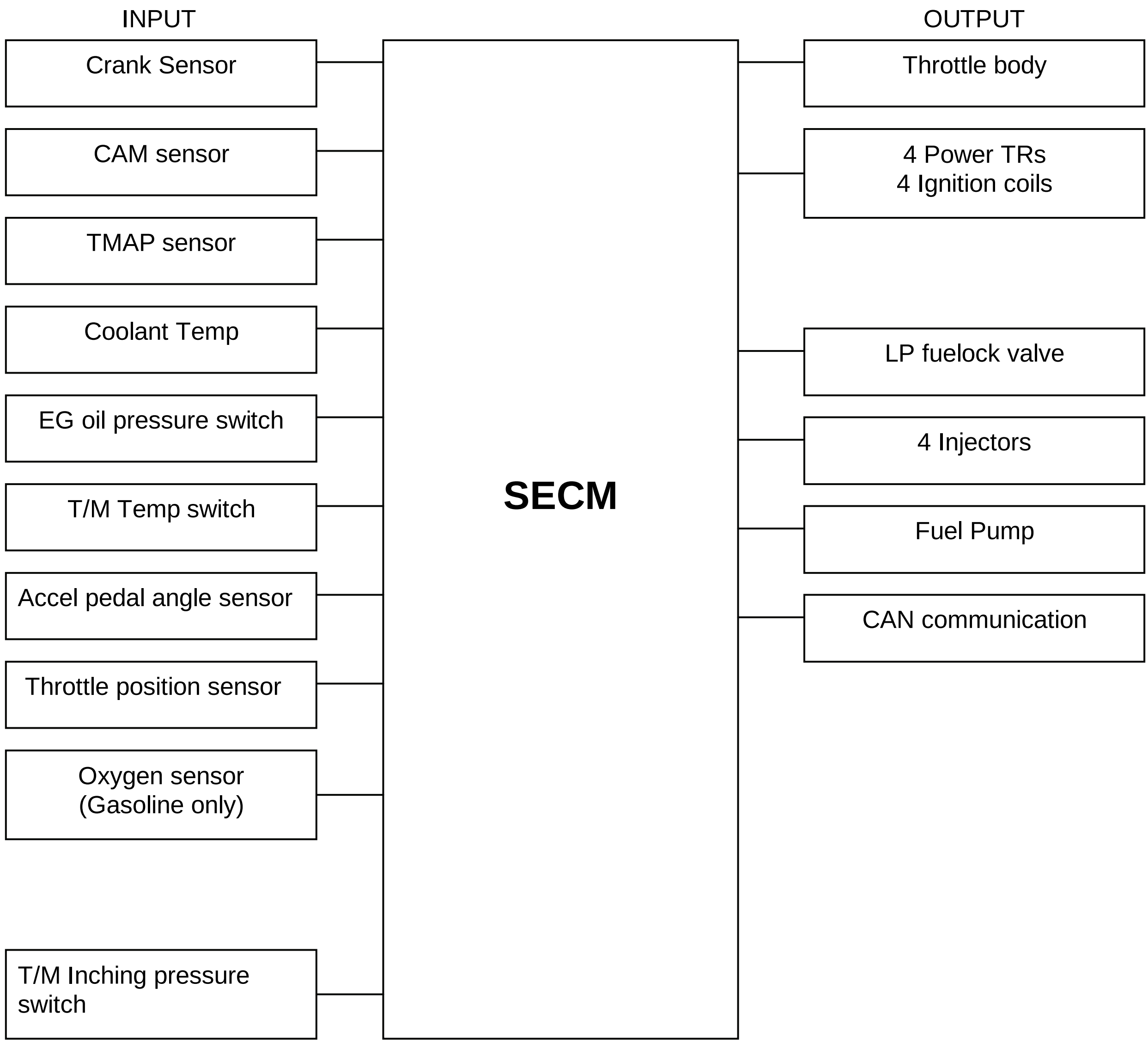


Figure 2. G420F Dual Fuel System

The LPG regulator and the mixer operate as an open loop system since no mixture adjustments are made by the SECM. The mixer does have an idle mixture adjustment and a power valve adjustment. Manifold pressure from the TMAP, rpm from the crank position sensor and throttle position is used by the SECM to calculate load. Feedback from the electronic throttle is provided to the SECM by the throttle position sensors (TPS).

Dual Fuel System of G420F



A dual fuel system operates on either LPG or gasoline. The fuel type can be switched while the engine is stopped or running at low speeds and low loads. The fuel selection switch is a three-position type where the center position is fuel off.

MPI (multi-point injection) system is used for G420FE dual fuel engine and G420F gasoline/dual fuel engine. On gasoline, the camshaft sensor along with the crankshaft sensor is used to control the fuel injectors and feedback from oxygen sensor is used by the SECM to adjust the gasoline delivery based on the exhaust emissions.

MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

- Fuel delivery system
- Spark-ignition control system
- Air throttle
- Sensors/Switches/Speed inputs

The chart below lists the MI-07 components required for a G420F engine operating on LP fuel.

Key Components

The MI-07 system functions primarily on engine components that affect engine

Q'ty		DESCRIPTION
G420FE -LP	G420F -LP	
1	1	Engine Control Module (SECM 48-pin)
1	1	Camshaft Position Sensor
1	1	Crankshaft Position Sensor
1	1	TMAP Sensor
1	None	Fuel Temperature Sensor
1	1	Transmission Oil Temperature Switch
2	None	Oxygen Sensors
1	1	Coolant Temperature Sensor
1	1	Engine Oil Pressure Switch
2	None	Fuel Trim Valve
4	4	Ignition Coils
4	4	Power TR
1	1	Fuel Lock Off Solenoid
N-2007	N-2001	LP Regulator
CA-100 (Certified)	CA-100	LP Mixer
1	1	Electronic Throttle Body

emissions and performance. These key components include the following:

- Engine/Combustion chamber design
- Intake/Exhaust valve configuration, timing and lift
- Intake/Exhaust manifold design
- Throttle body
- Air intake and air filter
- LPG mixer
- LPG pressure regulator
- Small engine control module (SECM), firmware and calibration †
- Fuel system sensors and actuators
- Ignition system including spark plugs, cables, coils and drivers
- Gasoline injectors and fuel pressure regulator (dual fuel system only)

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Open-loop fuel control with fuel specific controls for LPG
- Closed-loop fuel control with fuel specific controls for gasoline (MPI)
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Min/max governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Spark timing modifiers for temperature and fuel type
- Transient wall wetting compensation for gasoline
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics
MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

• Fuel filter (supplied by customer)
• Electric fuel lock-off solenoid valve
• Fuel pressure regulator/vaporizer
• Gas/Air mixer
• Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer. The mixer meters fuel delivery based upon airflow into the engine.

SECM
The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve. The lock-off solenoid is energized when fueling with LPG and the engine is turning. The lock-off is de-energized when engine rpm is not detected.

MI-07 LP Fuel Filter
The LP fuel filter of G420F engine is the same as that of G420FE engine. See, "G420FE EMS overview"

MI-07 Fuel Lock-Off (Electric)
The LP fuel lock-off of G420F engine is the same as that of G420FE engine. See, "G420FE EMS overview"

N-2001 Regulator/Converter
After passing through the electric fuel lock-off, liquid propane enters the N-2001 regulator/converter (Figure 4). The N-2001 functions as a fuel vaporizer, converting liquid propane to vapor propane and as a two-stage negative pressure regulator, supplying the correct vapor propane fuel pressure to the mixer.

The regulator is normally closed requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the

secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2001 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Figure 4. N-2001 Regulator

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced the liquid propane vaporizes and refrigeration occurs inside the regulator due to the large temperature drop inside the regulator from the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber. Figure 5 shows the heat chamber and the coolant passage in the N-2001 regulator.

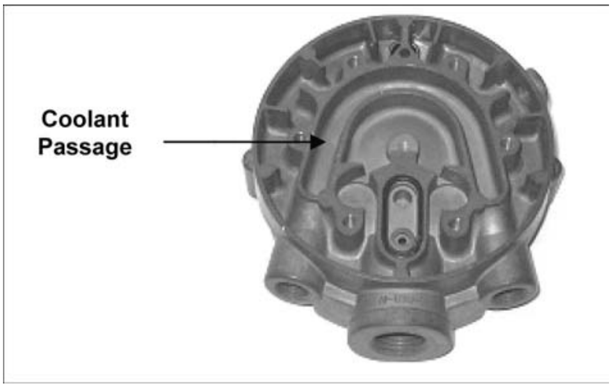


Figure 5. Heat Chamber and Coolant Passage

N-2001 Operation

Refer to Figure 6.
Liquid propane, at tank pressure, enters the N-2001 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever.
When the pressure in the expansion chamber reaches 1.5 psi (10.342 kPa it causes a pressure/ force imbalance across the primary diaphragm (8).
This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

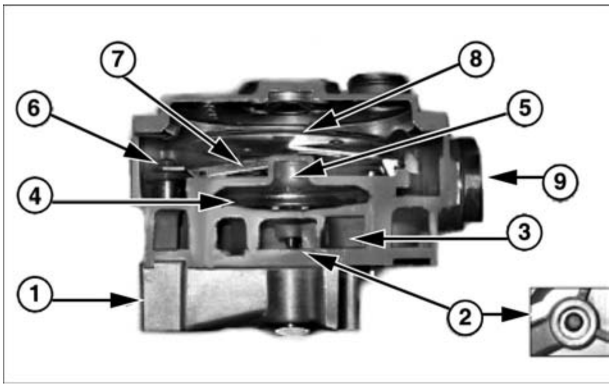


Figure 6. Parts View of N-2001 Regulator

Since the fuel pressure has been reduced from tank pressure to 1.5 psi (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened.
To open the secondary valve a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator (9), which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force

imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.

Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2001 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.

Figure 8. CA100 Mixer Attached to Throttle Body

(Refer **to Figure 98**.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5) and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

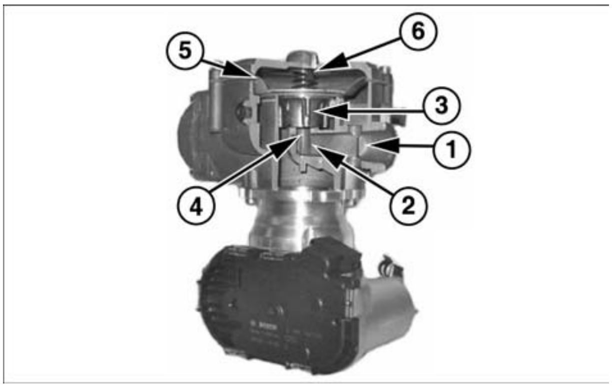


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

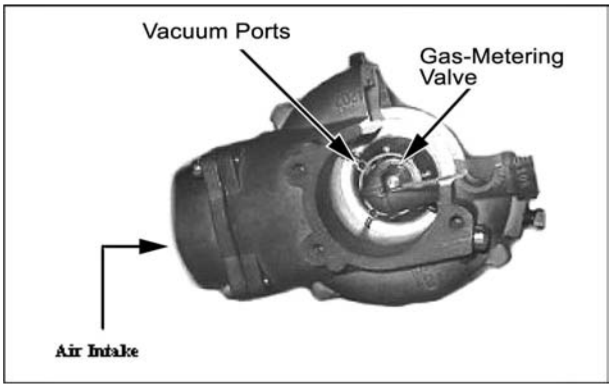


Figure 10. Bottom View of Air Valve Assembly


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.

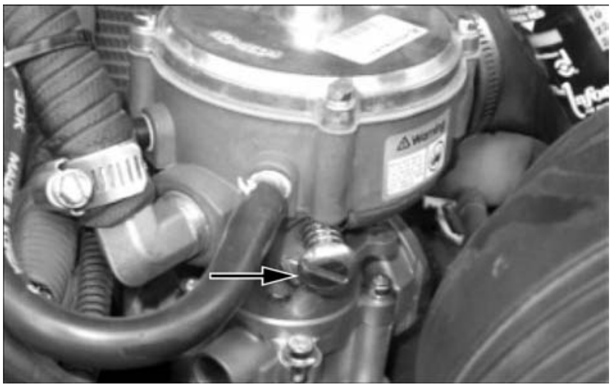


Figure 12. Idle Mixture Adjustment Screw

MPI Gasoline System Operation

The MPI Gasoline System of G420F engine is the same as that of G420FE engine. See, “MPI Gasoline System Operation of G420FE EMS overview”

Electronic Throttle System

The electronic throttle system of G420F engine is the same as that of G420FE engine. See, “Electronic throttle system of G420FE EMS overview”

Ignition System

The Ignition system of G420F engine is the same as that of G420FE engine. See, “Ignition system of G420FE EMS overview”

Exhaust System

Heated Exhaust Gas Oxygen Sensors (HEGO)

G420F MPI Gasoline system utilizes one HEGO (O2) sensor. It is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O2 sensor feedback, the MI-07 system supplies a optimized air-fuel.

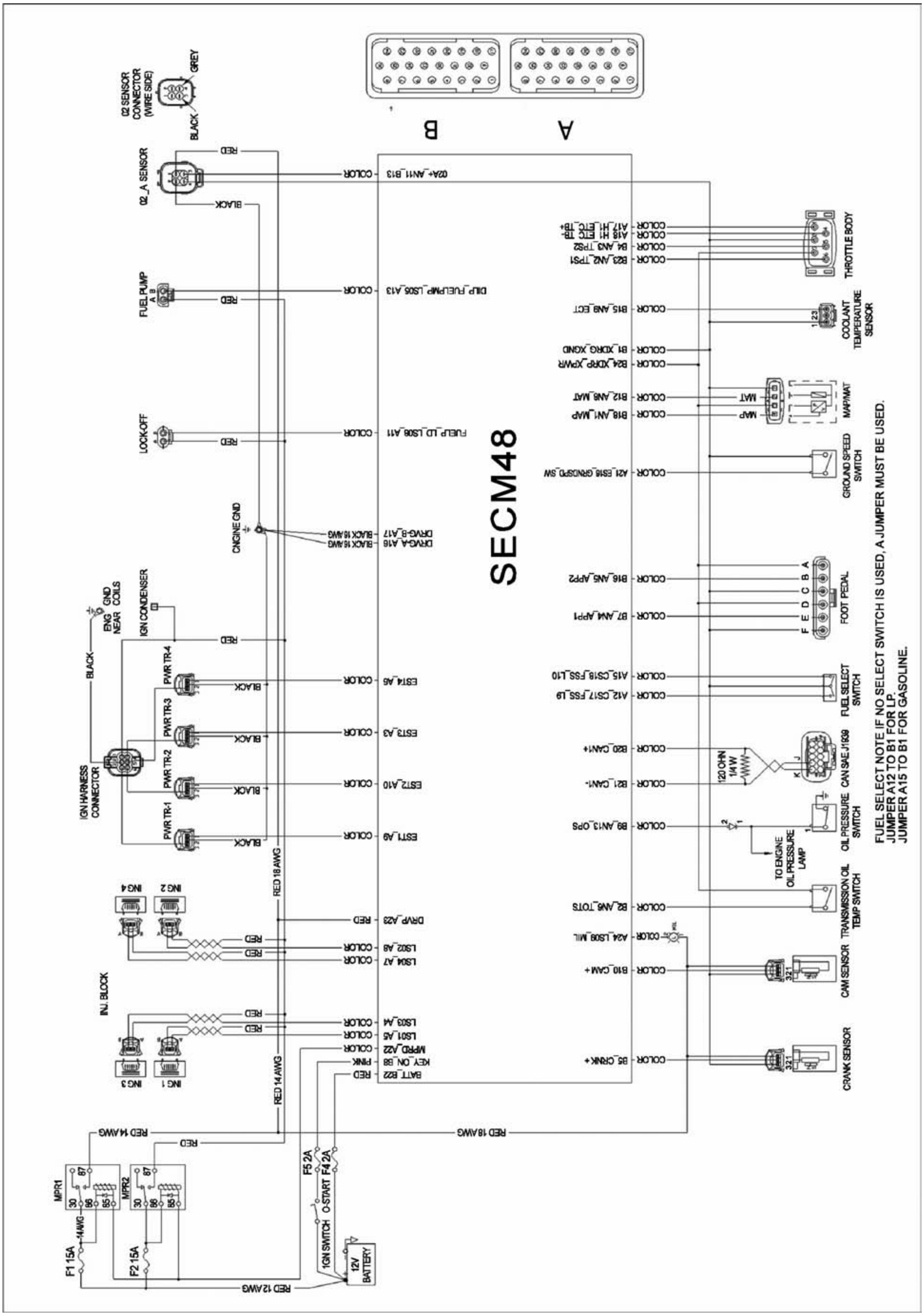
G420F LP system does not utilize HEGO sensor because it is open-loop system.

Figure 18. HEGO (O2) Sensor

SECM

The SECM of G420F engine is the same as that of G420FE engine. See, “SECM of G420FE EMS overview”

SECM Wiring Diagrams for G420F



EMS Inspection and Repair

Engine Control Module (SECM)

The 48-pin Small Engine Control Module (SECM) and sensors provide the computational power, algorithm logic, sensor inputs and control outputs to control the system. The SECM receives signals from the sensors, digitizes these signals, and then, through algorithms and calibration maps, computes the desired output response to effect control of fuel, spark and air to the engine. The SECM also provides a variety of other functions and features. These include system monitoring and diagnostics to aid in maintaining efficient system operation and auxiliary control.

SECM/sensor inputs and control output specifications are specific to the application, but include a selection of the following:

Analog Inputs

The 48-pin SECM is equipped with sufficient analog inputs for the following sensors.

- Manifold Absolute Pressure (MAP) 1bar MAP, 0 to 5 V
- Manifold Air Temperature (MAT)
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kohm to 85 ohm sensor range
- Throttle Position Sensor 1&2 (TPS1 & TPS2) 0 to 5 V
- Foot Pedal Position 1&2 (FPP1 & FPP2) 0 to 5 V
- Coolant Temperature Sensor (CTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 85 ohm sensor range
- Fuel Temperature Sensor (FTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 57 ohm sensor range
- HEGO (3) 0 to 1 V
- Auxiliary Analog Input (2) 0 to 5 V
- Battery Voltage (Vbatt) (1) 8-18 V

With the exception of battery voltage, all inputs are 0-5 Vdc, ground referenced. Resolution should be 0.1% or better. Accuracy should be 2% or better.

Frequency/Position Inputs

- Crankshaft position
  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors Permits speed resolution of 0.25 rpm and crankshaft position resolution of 0.5º
- Camshaft position
  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors.

Digital Inputs

- Oil pressure switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Transmission oil temperature switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Fuel select switch
  Three-position switch for bi-fuel applications to detect gasoline mode, LPG mode, and fuel off (center switch position)
- Ground speed select switch
  Permits selecting two different maximum engine speeds
- Vswitched
  Switched battery voltage

Outputs

- Saturated injector drivers (4)
  10A peak, 45 V max, 1 injector per channel capable of continuous on-time
  Driver circuit designed for minimum turn-on/turn-off delay
  Minimum pulse width resolution of 1 usec

- FTV drivers (2)
  10A peak, 45V max. To drive an on/off fuel trim valve with a minimum impedance of 5 ohms Capable of continuous on-time
  Drive circuit designed for minimum turn-on /turn-off delay
  FTVs will be pulse width modulated between 8 and 40 Hz with a minimum pulse width resolution of 50 usec

- Fuel lock-off solenoid valve
  Low side switch, 10A peak, 4A continuous 45 V max

- Gasoline fuel pump drive
  Low side switch, 10A, 4A continuous 45 V max

- Electronic Spark Timing (EST) (4)
  TTL compatible outputs Software configured for coil-on-plug ignition system

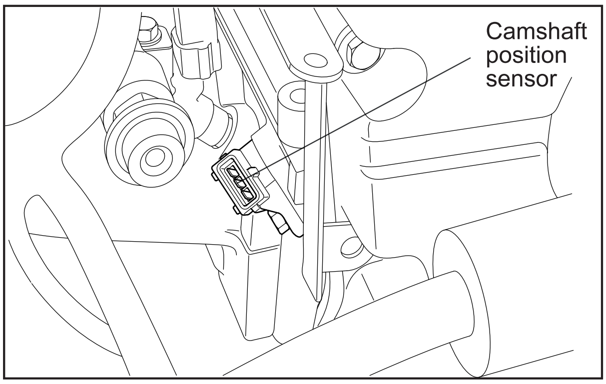
- Throttle control (1)
  H-Bridge, 5A peak, 2.5A continuous at 2500 Hz PWM includes current feedback for diagnostic purposes.

- MIL (malfunction indicator lamp)
  Low side switch, sufficient to drive a 7W incandescent lamp continuously

- CANBus
  CAN 2.0b serial communication for J1939 communications, programming and diagnostics.
  Requires proper termination resistance per CAN 2.0b.

Camshaft Position Sensor

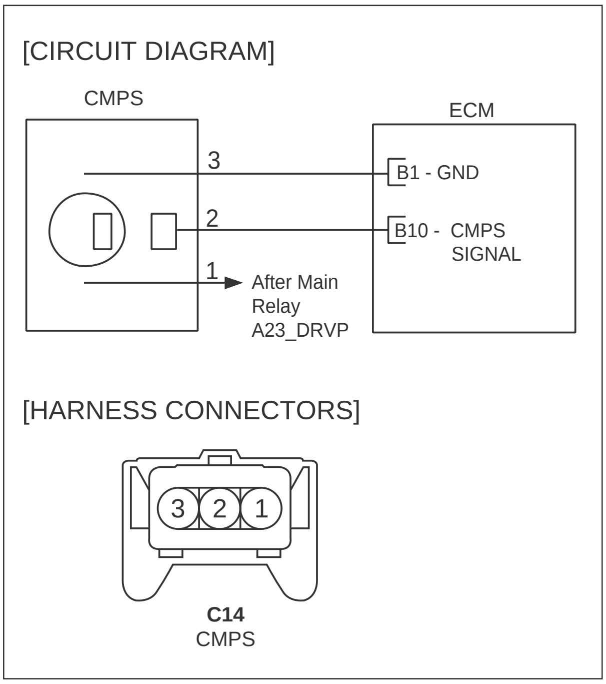
Component Location



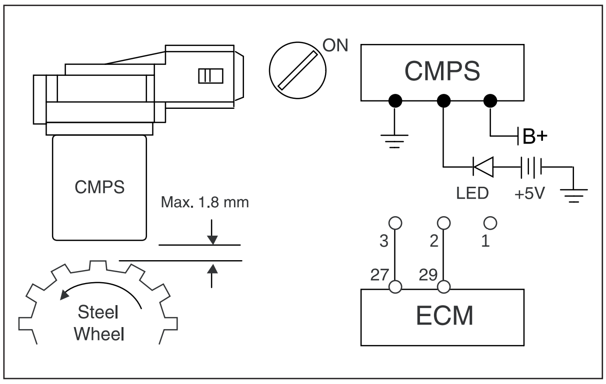
Description

The Camshaft Position Sensor (CMPS) is a sensor that detects the compression TDC of the NO.1 cylinder.
The CMPS consists of a hall type sensor and a target on the end of the in take camshaft.
When the target triggers the sensor, the sensor voltage is 5V. If not, the sensor voltage is 0V.
These CMPS signal is sent to the ECM and the ECM uses the CMPS signal for synchronizing the firing of sequential fuel injectors.

Schematic Diagram



Sensor Inspection



1. Turn ignition switch to OFF position and then disconnect CMPS connector.

2. Remove the CMPS from the engine.

3. Turn ignition switch to ON position.

4. Apply battery voltage to the terminal 1 and ground terminal 3 of CMPS as shown in the figure.

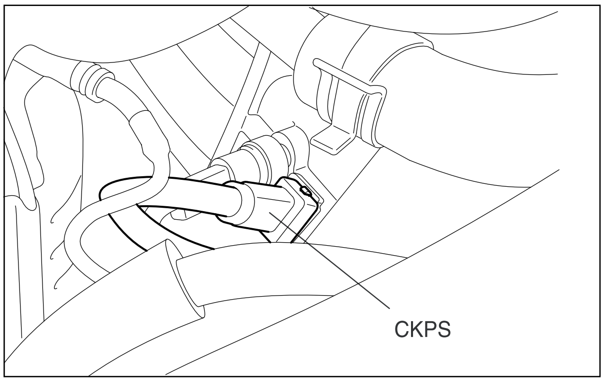
5. Install a LED between +5V power and CMPS terminal 2, and then set a steel wheel (or anything made of steel; hammer, wrench, bolt and nut etc.) at the CMPS's tip.

6. Rotate the steel wheel slowly and check if the LED flashes light.

- If the LED blinks, the CMPS works normally.

Crank Shaft Position Sensor

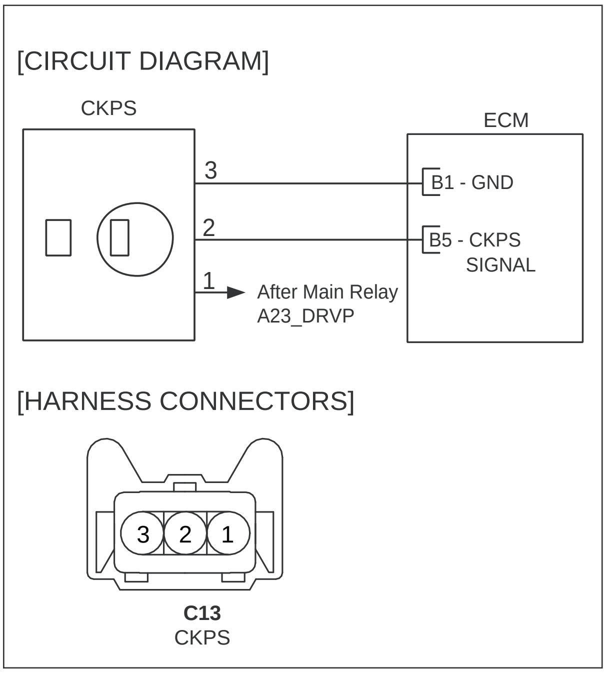
Component Location



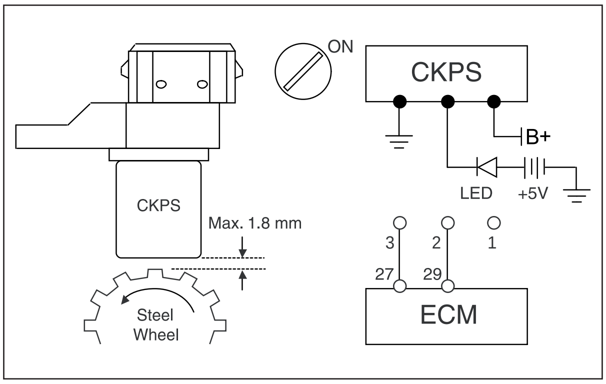
Description

The Crankshaft Position Sensor (CKPS) is a hall effect type sensor that generates voltage using a sensor and a target wheel mounted on the crankshaft; there are 58 slots in the target wheel where one is longer than the others.
When the slot in the wheel aligns with the sensor, the sensor voltage out put slow.
When the metal (tooth) in the wheel aligns with the sensor, the sensor voltage out puts high.
During one crankshaft rotation there are 58 rectangular signals and one longer signal. The ECM calculates engine RPM by using the sensor' signal and controls the injection duration and the ignition timing. Using the signal differences caused by the longer slot, the ECM identifies which cylinder is at top dead center.

Schematic Diagram



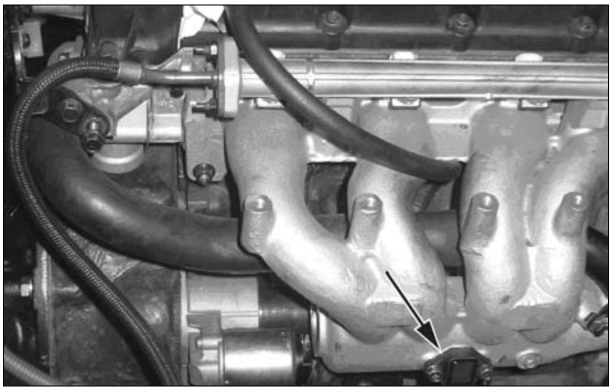
Sensor Inspection



1. Turn ignition switch to OFF position and then disconnect CKPS connector.
2. Remove the CKPS from the engine.
3. Turn ignition switch to ON position.
4. Apply battery voltage to the terminal 1 and ground terminal 1 and ground terminal 3 of CKPS as shown in the figure.
5. Install a LED between +5V power and CKPS terminal 2, and then set a steel wheel (or anything made of steel ; hammer, wrench, bolt and nut etc.) at the CKPS's tip.
6. Rotate the steel wheel slowly and check if the LED flashes light.

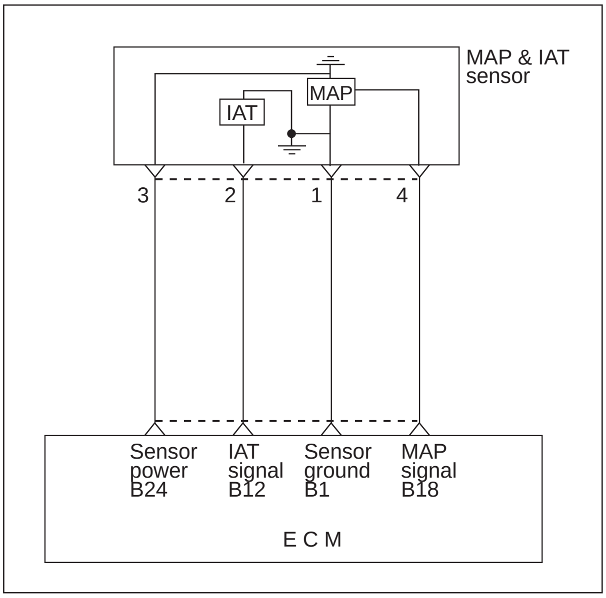
• If the LED blinks, the CKPS works normally.

MAP (Manifold Absolute Pressure) Sensor



The manifold absolute pressure (MAP) sensor is a pressure sensitive variable resistor. It measures changes in the intake manifold pressure which result from engine load and speed changes, and converts this to a voltage output. The MAP sensor is also used to measure barometric pressure at start up, and under certain conditions, allows the ECM to automatically adjust for different altitudes. The ECM supplies 5 volts to the MAP sensor and monitors the ECM supplies 5 volts to the MAP sensor and monitors the voltage on a signal line. The sensor provides a path to voltage on a signal line. The sensor provides a path to ground through its variable resistor. The MAP sensor in put affects fuel delivery and ignition timing controls in the ECM.

Ciruit Diagram



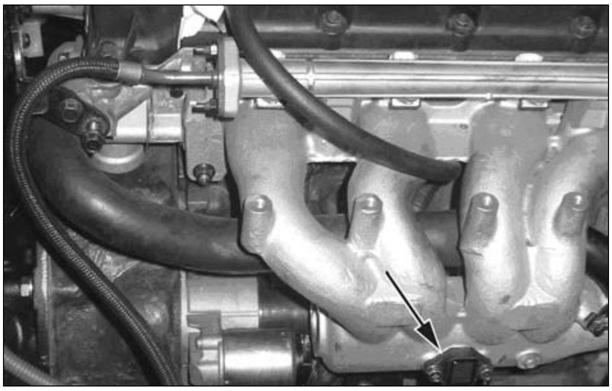
Sensor Inspection

1. Measure the voltage between terminals 1 and 4 of the MAP sensor connectors.
   Terminal 4 : MAP sensor ground
   Terminal 1 : MAP sensor output

Engine state	Test specification
Ignition SW. ON	4~5V
At idle	0.5~2.0V

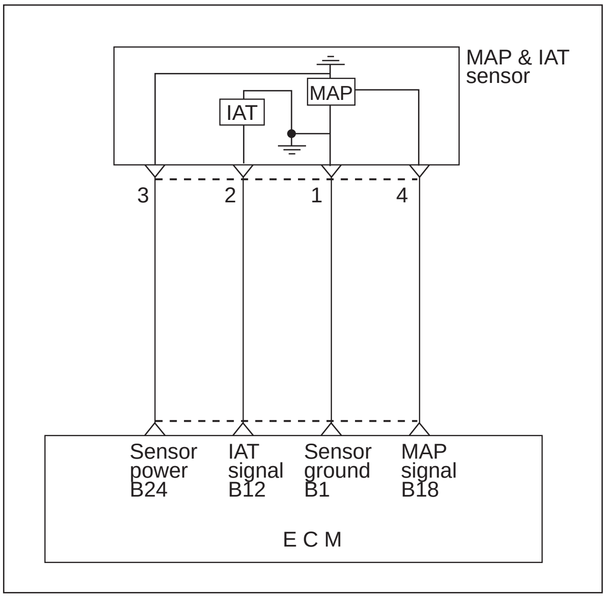
2. If the voltage deviates from the standard value, replace the MAP sensor assembly.

IAT (Intake Air Temperature) Sensor



The intake air temperature sensor (IAT Sensor), built in to the MAT sensor, is a resistor-based sensor detect the intake air temperature. According to the intake air temperature information frim the sensor, the ECM will control the necessary amount of fuel injection.

Ciruit Diagram



Sensor Inspection

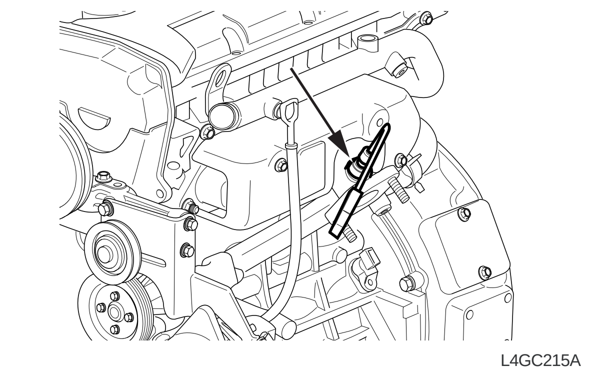
1. Using a multimeter, measure the IAT sensor resistance between terminals 3 and 4.

IG.SW.ON	Temperature ℃ (°F)	Resistance(kΩ)
	0 (32)	4.5 ~ 7.5
	20 (68)	2.0 ~ 3.0
	40 (104)	0.7 ~ 1.6
	80 (176)	0.2 ~ 0.4

2. If the resistance deviates from the standard value, replace the intake air temperature sensor assembly.

Oxygen Sensor (Pre-Catalyst)

Component Location



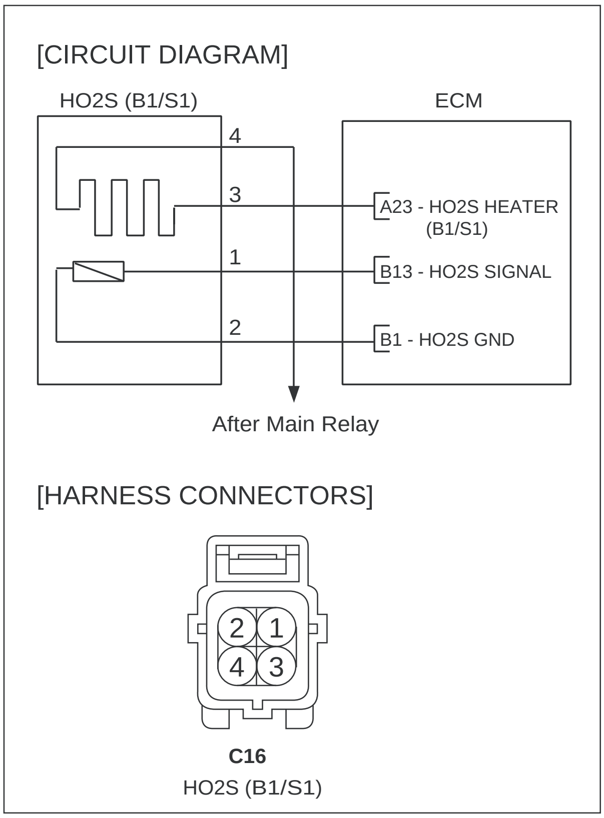
Description

The heated oxygen sensor is mounted on the front side of Catalytic Muffler, which detects the oxygen concentration in the exhaust gas. The heated oxygen sensor produces a voltage that varies between 0V and 1V. When the air/fuel ratio is lean, the oxygen concentration in the exhaust gas increases and the front HO2S outputs a low voltage (approximately0~0.1V). When the air/fuel ratio is rich, the oxygen concentration in the exhaust gas decreases and the front HO2S outputs a high voltage (approximately0.8~1V). The ECM constantly monitors the HO2S and increases or decreases the fuel injection duration by using the HO2S signal, which is called closed-loop fuel control operation.

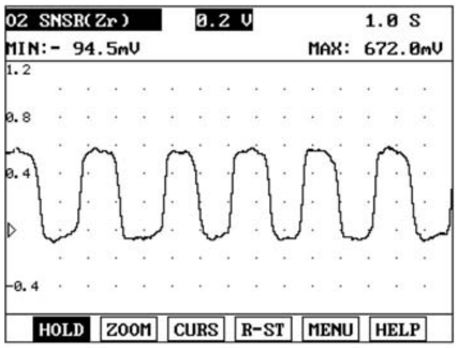
Specification

Temperature		Front HO2S Heater Resis-tance(Ω)	Temperature		Front HO2S Heater Resistance (Ω)
(℃)	(˚F)		(℃)	(˚F)	
20	68	9.2	400	752	17.7
100	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14.6	700	1,292	22.5

Schematic Diagram



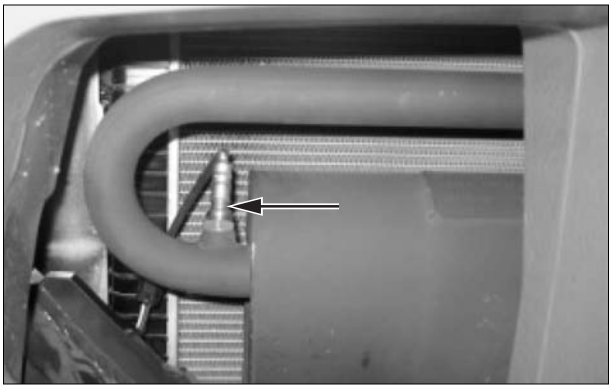
Signal Wave Form



If you release the accelerator pedal suddenly after engine running about 2600 rpm, fuel supply will stop for short period and the O2 sensor service data will display values 200mV or lower. When you suddenly press on the accelerator pedal down, the voltage will reach 0.6 ~ 1.0 V. When you let the engine idle again, the voltage will fluctuate between 200 mV or lower and 0.6 ~ 1.0 V. In this case, the O2sensor can be determined as good.

Oxygen Sensor (Post-Catalyst)

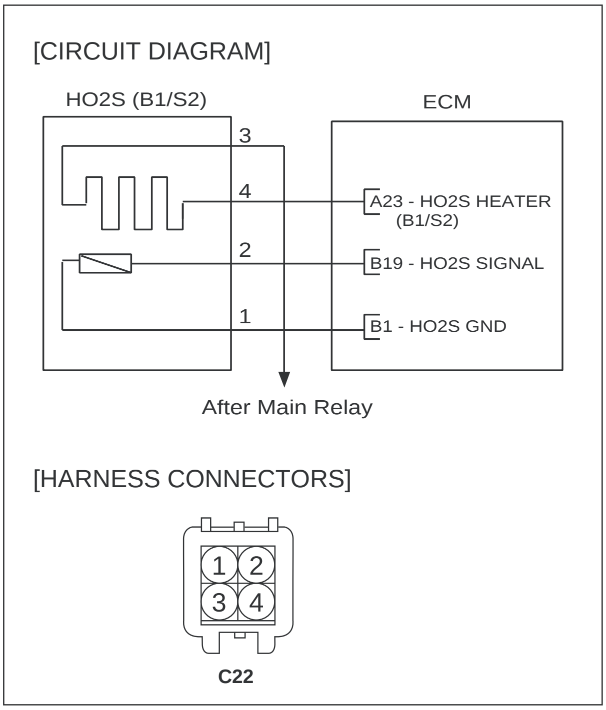
Component Location



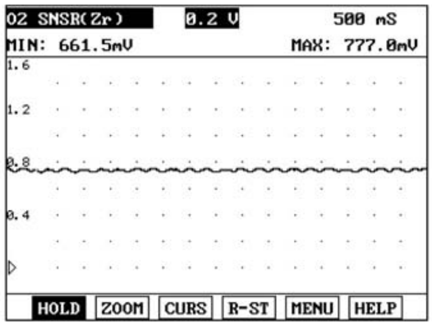
Description

The rear heated oxygen sensor is mounted on the rear side of the Catalytic Muffler, which detects the catalyst efficiency. The rear heated oxygen sensor (HO2S) produces a voltage between 0V and 1V. This rear heated oxygen sensor is used to estimate the oxygen storage capability. If a catalyst has good conversion properties, the oxygen fluctuations are smoothed by the oxygen storage capacity of the catalyst. If the conversion provided by the catalyst is low due to aging, poisoning or misfiring, then the oxygen fluctuations are similar to signals from the front oxygen sensor.

Schematic Diagram



Signal Wave Form



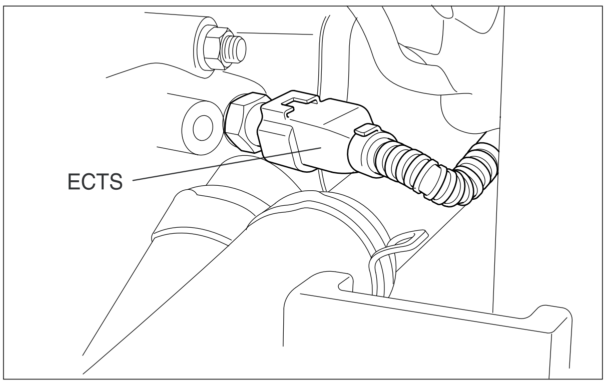
The amplitude of the signal output of the rear HO2S is small compared to the front HO2S because the rear HO2S detects emission gas purified by the catalytic converter. This illustration is the normal signal waveform of the rear HO2S at idle.

Specification

Temperature		Rear HO2S Heater Resis-tance(Ω)	Temperature		Rear HO2S Heater Resistance(Ω)
(℃)	(℉)		(℃)	(℉)	
20	68	9.2	400	752	17.7
10	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14..6	700	1,272	22.5

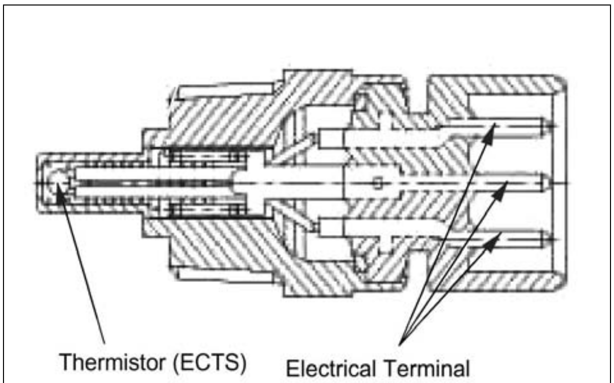
ECT (Engine Coolant Temperature) Sensor

Component Location

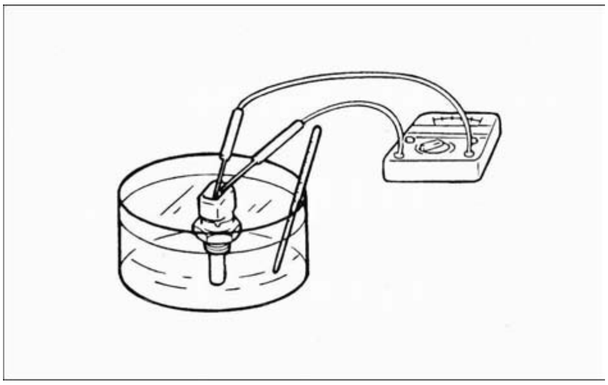


Description

The Engine Coolant Temperature Sensor (ECTS) is located in the engine coolant passage of the cylinder head for detecting the engine coolant temperature. The ECTS uses a the rmistor whose resistance changes with the temperature. The electrical resistance of the ECTS decreases as the temperature increases, and increases as the temperature decreases. The reference 5 V in the ECM is supplied to the ECTS via a resistor in the ECM. That is, the resistor in the ECM and the thermistor in the ECTS are connected in series. When the resistance value of the thermistor in the ECTS changes according to the engine coolant temperature, the output voltage also changes. During cold engine operation the ECM increases the fuel injection duration and controls the ignition timing using the information of engine coolant temperature to avoid engine stalling and improve drivability.



Sensor Inspection



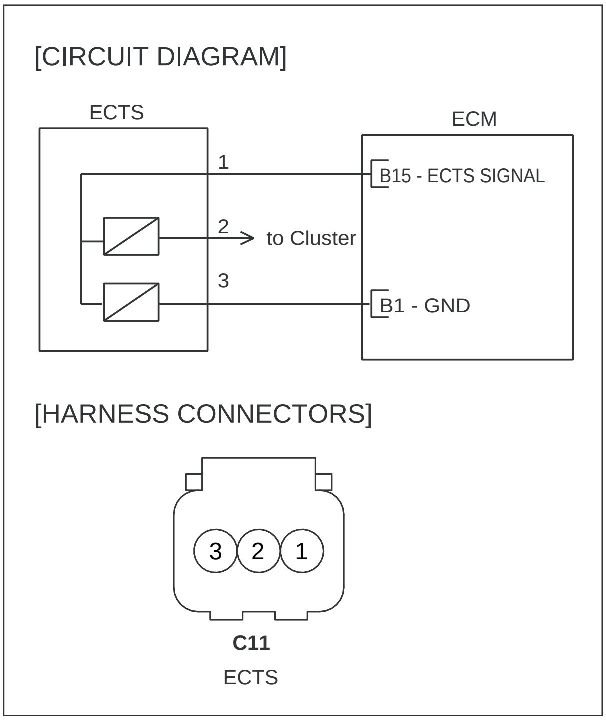
1. Remove the engine coolant temperature sensor from the intake intake manifold.

2. With the temperature sensing portion of the engine coolant temperature sensor immersed in hot water, check resistance.

Temperature ℃ (°F)	ECTS Resistance(kΩ)
-20(-4)	14.13~16.83
0(32)	5.79
20(68)	2.31~2.59
40(104)	1.15
60(140)	0.59
80(176)	0.32

3. If the resistance deviates from the standard value greatly, replace the sensor.

Schematic Diagram



Installation

1. Apply sealant LOCTITE 962T or equivalent to threaded portion.

2. Install engine coolant temperature sensor and tighten it to specified torque.

Tightning torque

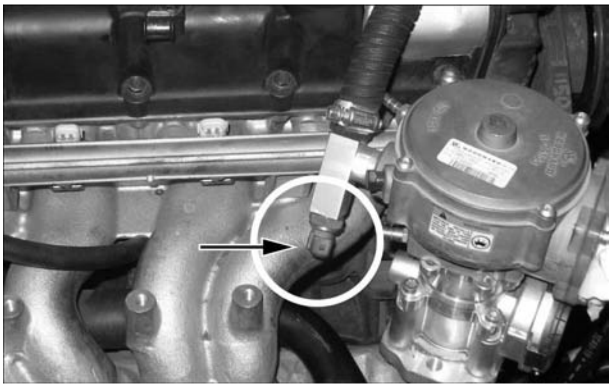
Engine coolant temperature sensor "
15~20Nm (150~200 kg.cm, 11~15 lb.ft)

---

3. Connect the harness connector securely.

LP Fuel Temperature Sensor

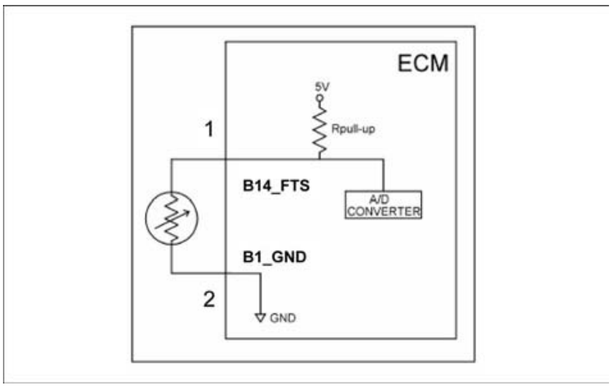
Location



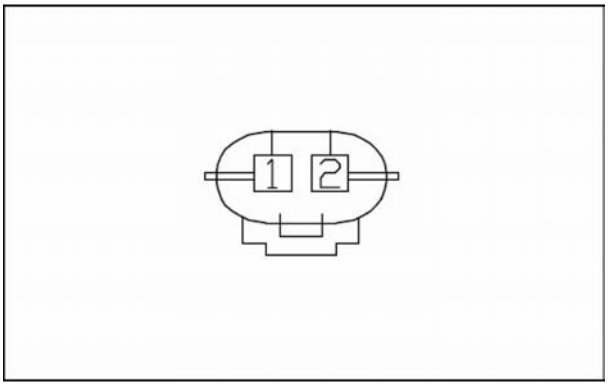
Description

The LP Fuel Temperature Sensor (FTS) is located in the LP fuel passage of the LP mixer for detecting the LP fuel temperature. The FTS uses a thermistor whose resistance changes with the temperature. The electrical resistance of the FTS decrease as the temperature increase, and increase as the temperature decrease. The reference 5V in the ECM is supplied to the FTS by way of a resister in the ECM. That is, the resistor in the ECM and the thermistor in the FTS are connected in series. When the resistance value of the thermistor in the FTS changes according to the LP fuel temperature, the output voltage also change.

[Circuit Diagram]



[Harness Connectors]



Inspection

1. Remove the LP fuel temperature sensor from the adapter connected to LP mixer.

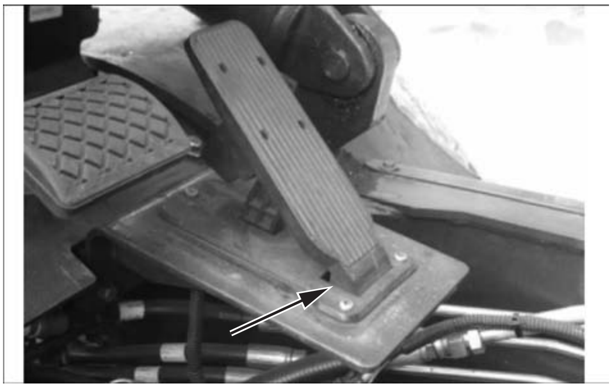
2. With the temperature sensing portion of the LP engine fuel temperature immersed in hot water, check resistance.

Temperature °C (°F)	FTS Resistance (Ohms)
-20(-4)	15462
0(32)	5896
20(68)	2498
40(104)	1175
60(140)	596
80(176)	323

3. If the resistance deviates from the standard value greatly, replace the sensor.

Angle Sensor-Accelerator

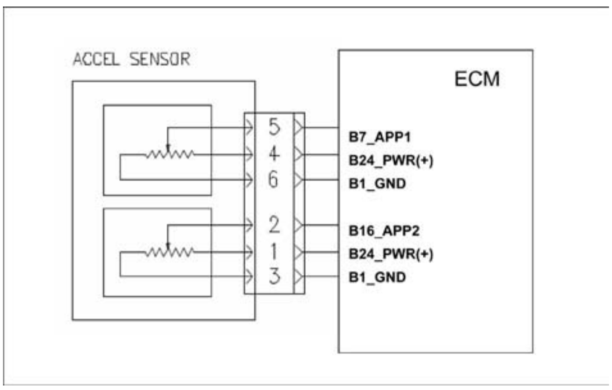
Location



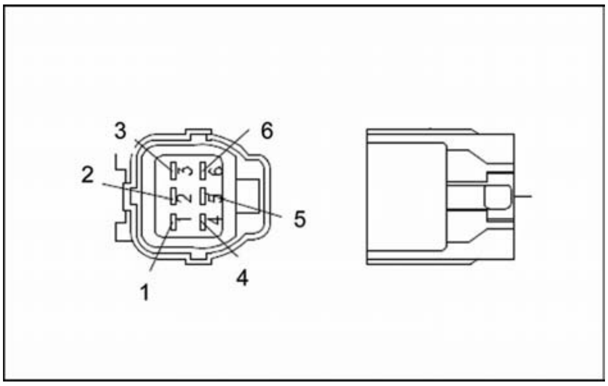
Description

Angle Sensor-Accelerator is located in the accelerator pedal assembly. The engine speed management deals with a Drive-by-wire system. Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the ECM is electronically connected both to the foot pedal assembly and the throttle body. The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed. The foot pedal assembly uses two potentiometers to detect pedal position. These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM. The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly.

[Circuit Diagram]



[Harness Connectors]



Inspection

1. Disconnect the Accelerator Pedal's connector from the main engine harness.

2. Inspect the electrical conditions with a follow basic specification.

Signal output is on condition that input voltage is 5V±0.5%
Rated current : 20Ma,
Power : 100mW,
Wire width : 20AWG
- At start point : Signal 'A' 0.4V±0.1V
  Signal 'B' 4.5V±0.1V
- At end point(Push for end) :
  Signal 'A' 3.60V±0.15V
  Signal 'B' 1.39V±0.15V

3. If the result value is out of the specification, replace the Accelerator Pedal.

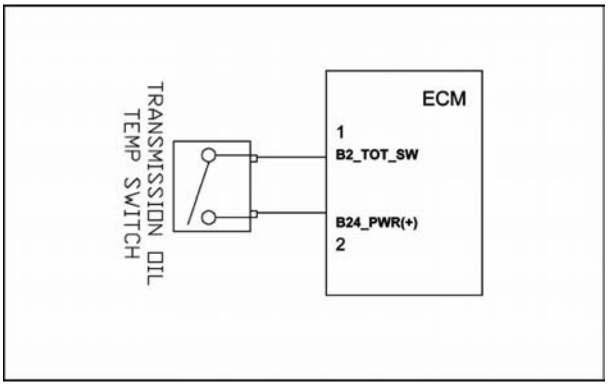
Transmission Oil Temperature Switch

Location

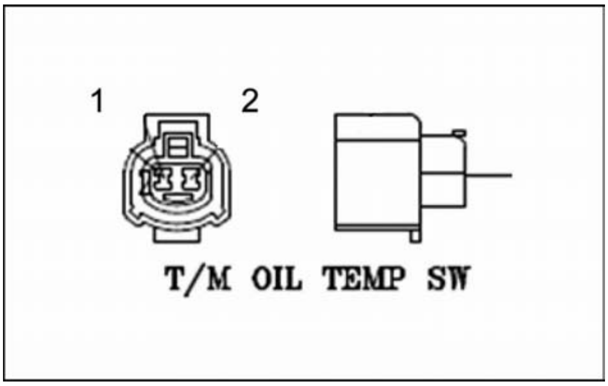
Description

Transmission Oil Temperature Switch is located in the adapter on transmission (T/M) for operating by the transmission (T/M) oil temperature change. This switch is normally open, and then it is closed as the T/M oil temperature Increases to the 125±3°C. Actually if the switch is closed by high T/M oil temperature, the ECM makes engine shutdown with fault set. If the T/M oil temperature decreases to the 118°C, the switch is open again and the engine also can run. This function can protect the engine of Tier-3 and Non cert folk lift trucks from damage as overheating.

[Circuit Diagram]



[Harness Connectors]



Inspection

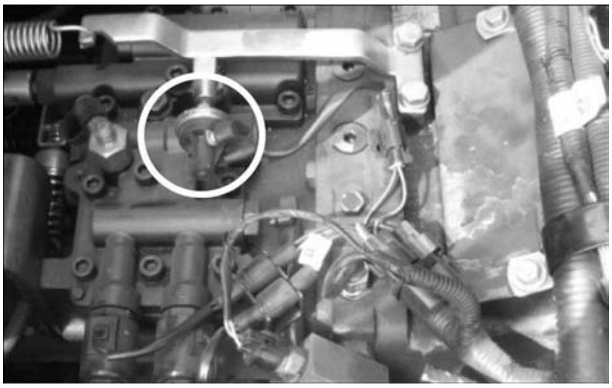
1. Remove the Transmission Oil Temperature Switch from the transmission.

2. Use an ohmmeter to check the continuity between the 1 terminal and the 2 terminal. If there is continuity, replace the Transmission Oil Temperature Switch.

3. The Transmission Oil Temperature Switch is the 'ON/OFF' switch. So during the normal status the switch circuit should be open.

Ground Speed Limit Switch (optional)

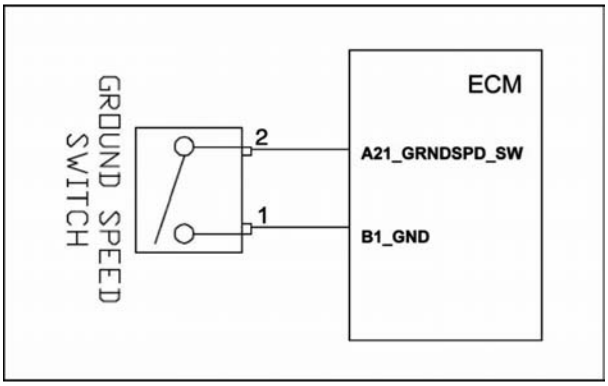
Location



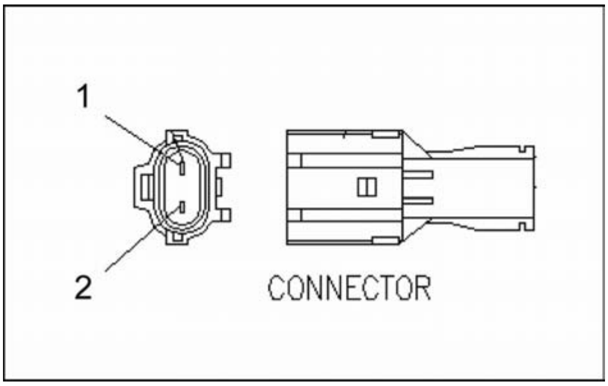
Description

Ground Speed Limit Switch is located in the pressure port on transmission (T/M) for operating by the transmission (T/M) oil pressure change. This switch is normally opened, and then it is closed as the T/M oil pressure increases. Actually the switch is closed by increasing of the T/M oil pressure after engine cranking. And if the inching pedal is pushed by a driver the switch is opened again by decreasing of the T/M oil pressure. ECM can control the travel speed of the folk lift trucks with this switch. Also the maximum travel speed of Tier-3 and Non cert fork lift trucks is an optional feature that can be easily activated using the MotoView Service Tool. This feature may be of particular interest to customers with indoor warehouse operations.

[Circuit Diagram]



[Harness Connectors]



Inspection

1. Remove the Ground Speed Limit Switch from the transmission.

2. Use an ohmmeter to check the continuity between the 1 terminal and the 2 terminal. If there is continuity, replace the Ground Speed Switch.

3. The Ground Speed Limit Switch is the 'ON/OFF' switch. So during the normal status the switch circuit should be open.

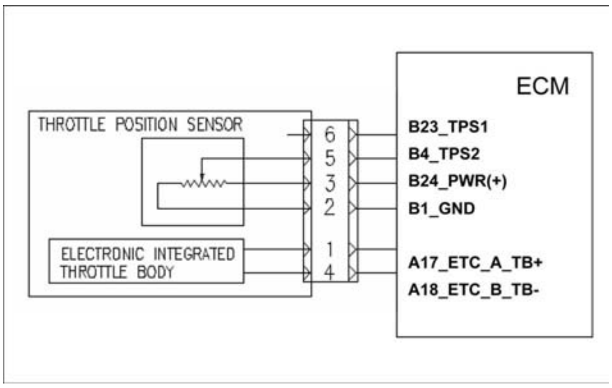
Electronic Throttle Body

Location

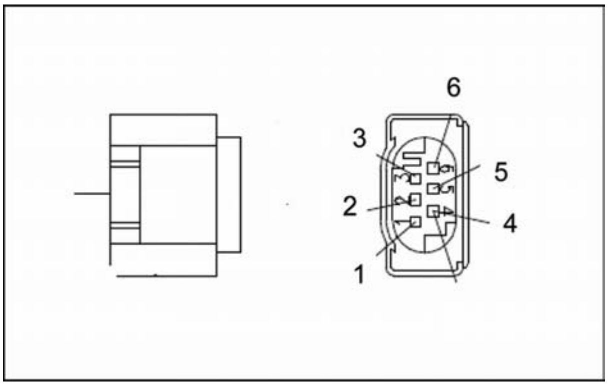
Description

The MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm electronic throttle body DV-E5. The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

[Circuit Diagram]



[Harness Connectors]



Inspection

1. Check for loose, dirty or damaged connectors and wires on the harness

2. Check the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips

3. Check the resistance of TPS sensor. (refer as blow chart)

SENSOR	POINT TO POINT	EXPECTED RANGE
TPS (Throttle Position Sensor)	TPS PIN 2(GND) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/-30%
	TPS PIN 3(PWR) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/-30%
	TPS PIN 1(+DRIVER) TO PIN 4(-DRIVER)	~3.0KΩ +/-30%

Chapter 6. LPG FUEL DELIVERY SYSTEM

G420FE LP System Inspection and Repair

Removal and Installation

⚠ WARNING - PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/ converter or mixer.

Hose Connections

Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagrams below for proper routing and maximum hose lengths when reinstalling system components.

Certified System Connections

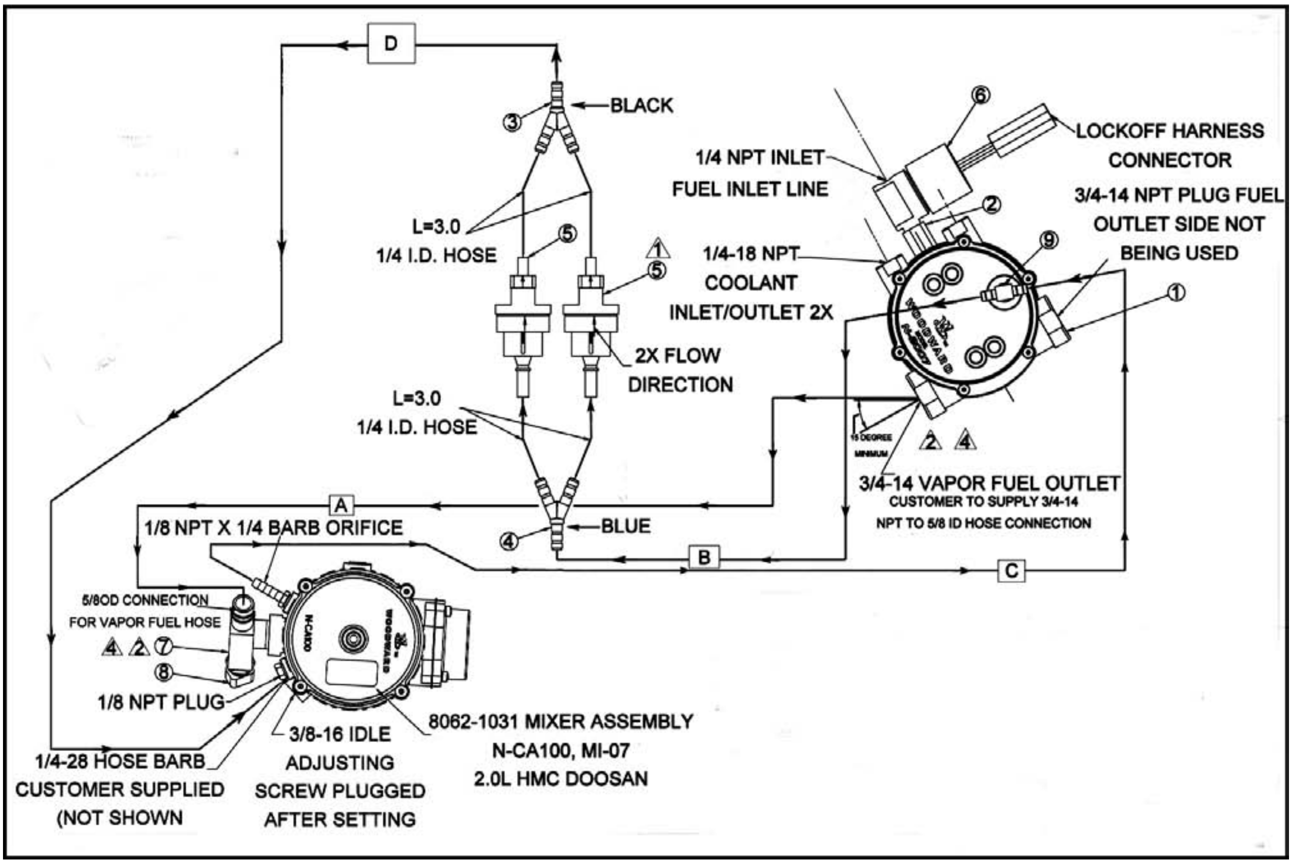


Figure 26. Hose Connections for Certified Systems

Diagram Notes

- 1 Trim valves must be positioned vertically
- 2 Only one 90° fitting permissible on vapor fuel line between mixer and regulator
- 3 Preferred mounting of regulator is off engine
- 4 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.46" (11.68mm)
- A 5/8" (15.9 mm) I.D. Vapor hose. L= 18-30" (457-762mm) Maximum length 30" (762mm)
- B 1/4" (6.35mm) I.D. Hose. L= 13-20" (330-508mm) Maximum length specified by engine manufacturer
- C 1/4" (6.35mm) I.D. Hose. L= 21-32" (533 -813mm) Maximum length specified by engine manufacturer
- D 1/4" (6.35mm) I.D. Vacuum Hose. L= 24-35.5" (610-902mm) Maximum length specified by engine manufacturer
- 1 N-2007 Regulator
- 2 5/8" (15.9mm) Hex Nipple, 1/4 x 18 NPT, 2-1/2" (63.5mm) L
- 3 Plastic WYE Fitting (black color) for 1/4" (6.35mm) I.D. Tube Hose
- 4 Plastic WYE Fitting (blue color) for 1/4" (6.35mm) I.D. Tube Hose
- 5 Valve (TEV Bosch Canister)
- 6 Solenoid (AFS Lock Off Valve)
- 7 Temperature Sensor Adapter
- 8 Fuel Temperature Sensor
- 9 Brass Tee Fitting. 1/4 x 1/8 NPTF x 1/4" [6.35mm] Tube

Removal and Installation of N-2007 LP Regulator

Follow the procedures below for removal and reinstallation of the N-2007 regulator in certified systems.

N-2007 Removal Steps

Refer to **Figure 28.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

5. Remove the four rear-mounting bolts that hold the regulator to the support bracket. This will allow easier access to the remaining hose clamps.

6. Remove the two cooling lines (4) from the regulator. NOTE: Either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

7. Remove the fuel vapor outlet hose (5) from the regulator.

8. Remove the nipple extension (6) with the lock-off from the regulator.

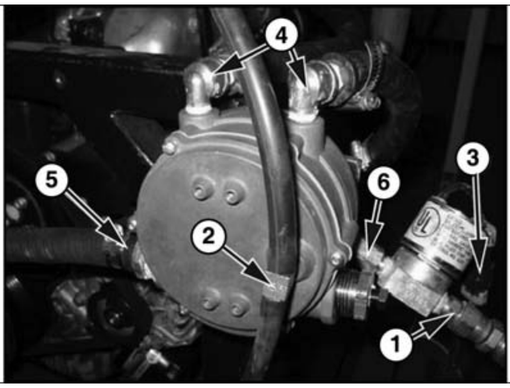


Figure 28. N-2007 Regulator in Certified System

N-2007 Installation Steps

Refer to **Figure 28.**

1. Install the nipple extension (6) with the lock-off to the regulator.

2. Install the fuel vapor outlet hose (5) to the regulator.

3. Install the two cooling lines (4) to the regulator.

4. Install the four rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 60-70 lbf-in (6.78-7.91 N-m).

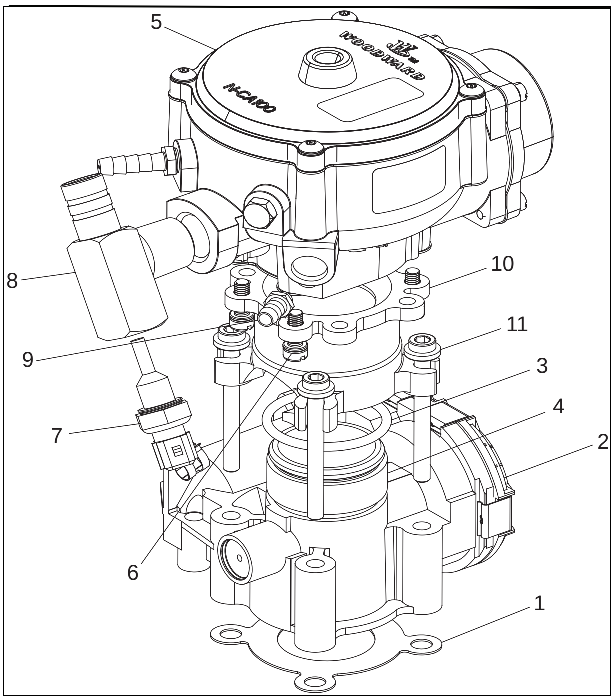
5. Install the fuel inlet line (1) to the lock-off, the two vacuum lines (2) to the branch-tee fitting in the regulator vent and re-connect the lock-off connector (3).

6. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G420FE

Follow the procedures below for removal and reinstallation of the CA100 mixer in certified systems.

CA100 Certified Mixer Removal Steps



1. Gasket-ITB
2. ITB
3. O-Ring
4. O-Ring Spacer
5. Mixer
6. Bolt
7. Fuel Temp Sensor
8. Adapter-Fuel Temp Sensor
9. Fitting-Vacuum Small
10. Apollo Adapter-ITB, Mixer
11. Bolt

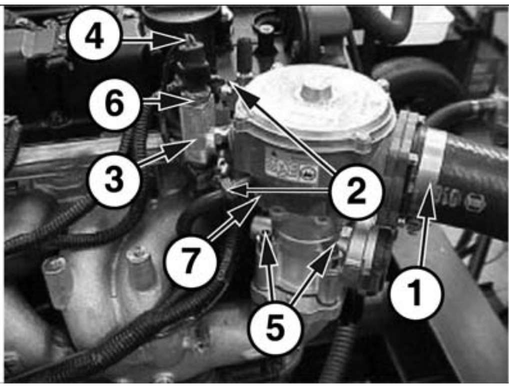


Figure 30. CA100 Mixer in Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the air cleaner hose (1).

5. Mark the two vacuum lines to the mixer for identification, as they must be installed correctly for proper operation. Remove the two vacuum lines (2).

6. Remove vapor fuel inlet line from the fuel temperature sensor adapter (3).

7. Disconnect the fuel temperature sensor connector (4).

8. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector.

9. Loosen the four bolts that secure the mixer/adapter/throttle body assembly to the intake manifold.

10. Remove the mixer (7), the adapter, and the throttle body (**5**) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

11. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

12. Remove the four mounting screws that attach the throttle body adapter to the mixer.

13. Remove the fuel temperature sensor (not shown) from the tee .

14. Remove the fuel temperature sensor fitting from the mixer. Take note of the fitting’s orientation on the mixer, as it must be reinstalled correctly for proper fit.

15. Remove the short vacuum port barb from the mixer. (See **Figure 32** for location of port barb on mixer.)

CAUTION

The 1/8” NPT x 1/4” hose barb fitting that is installed in the mixer housing uses a specific machined orifice size through the fitting. This orifice fitting is part of the mixer assembly and is an integral part of the MI-07 control. If this fitting is damaged the mixer will need to be replaced. DO NOT replace this fitting with a standard hose barb fitting or use a drill bit to clean out the fitting passage way.

NOTE : A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

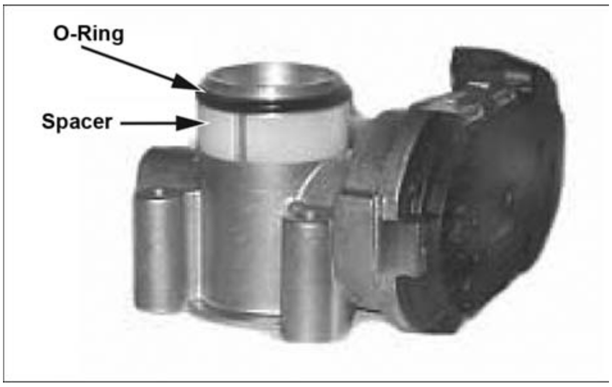


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

CA100 Certified Mixer Installation Steps

Refer to **Figure 30.**

1. Install the vacuum port barb below the idle set screw on the mixer (7).

2. Install the fuel temperature sensor adapter to the mixer.

3. Install the fuel temperature sensor to the adapter (6).

4. Install the four mount screws that attach the throttle adaptor to the mixer. See Figure 32. Torque bolts to 30-40 lbf-in (3.39-4.52 N-m).

5. Install the mixer/adapter assembly to the throttle by gently pushing downwards.

6. Install the four bolts that mount the throttle adapter to the electronic throttle body (5).

7. Re-connect the fuel temperature sensor connector (4).

8. Install the vapor fuel inlet line to the fuel temperature sensor adapter (3).

9. Install the two vacuum lines to the mixer using the previous marks for identification. Vacuum lines must be installed correctly for proper operation.

10. Install the air cleaner hose (1).

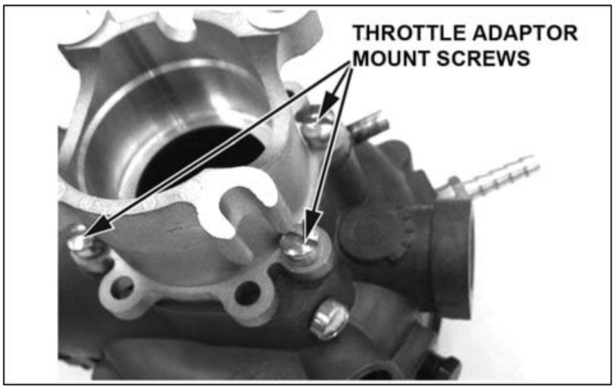


Figure 32. Throttle Adapter Mount Screws

Tests and Adjustments

⚠ WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

N-2007 Regulator Service Testing

For checking the N-2007 regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the N-2007 regulator). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4" NPT x 1/4" hose barb

3. Union Tee 1/4" NPT with three 1/4" NPT x 1/4" hose barb

4. Vacuum hose

5. 0-3" WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 34). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2" WC on the gauge. This vacuum signal opens the secondary valve in the N-2007 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-0.5 +/- 0.35 " WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

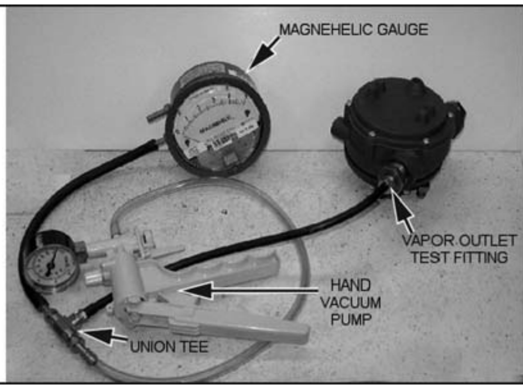


Figure 34. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Shop air pressure regulator adjusted to 100 psi

2. Shop air hose fitting (1/4" NPT to air hose)

3. Air hose

4. Test gauge fitting (1/16" NPT x 1/4" hose barb)

5. Vacuum hose or vinyl tubing

6. 0-60" WC Magnehelic gauge (inches of water column)

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16" NPT hose barb fitting (Figure 35).

2. Connect a compressed air line (shop air ~100psi) to the liquid propane fuel inlet of the N-2007 regulator (Figure 35).

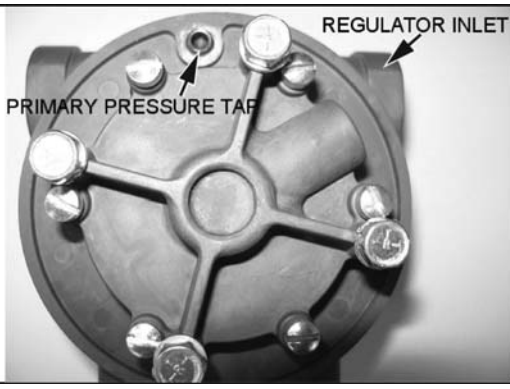


Figure 35. Primary Stage Test Connection

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 36) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60” of water column on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

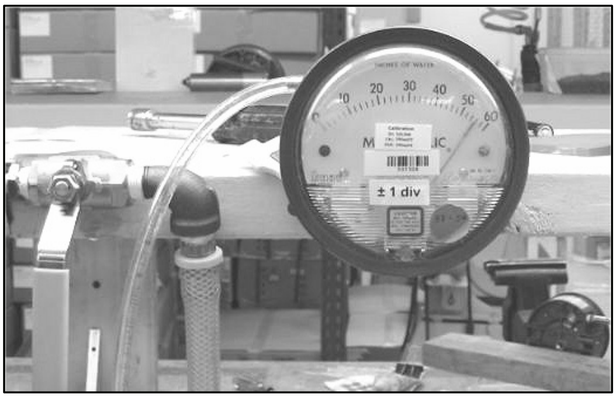


Figure 36. Magnehelic Gauge Connection to Hose Barb

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2007 regulator.

NOTE : The N-2007 primary stage pressure can also be tested at idle on a running engine. The N-2007 primary pressure should be between 40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 rpm, idle.

⚠ CAUTION

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4" (6.35mm) NPT with three 1/4" (6.35mm) NPT x 1/4" (6.35mm) hose barbs

2. Vacuum hose

3. 0-20" H2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5" and 8" H2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

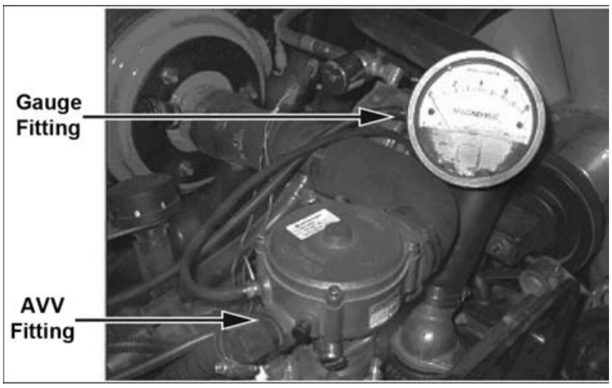


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.

The initial ignition timing needs to be set by the MOR. This setup requires a specific technique for each engine installation.

Connection of the MI-07 Service Tool

To use the Service Tool, a USB (Universal Serial Bus) to CAN (Controller Area Network) communication adapter by KVaser will be required along with a Crypt Token (Figure 38). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (Figure 39).

2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. (*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).

3. Connect a timing light to the engine.

4. Turn the ignition key to the ON position (Do Not Start the Engine).

5. Launch the MotoView program on your computer and open the Service Tool display (Figure 40).

Figure 38. KVaser Communication Adapter

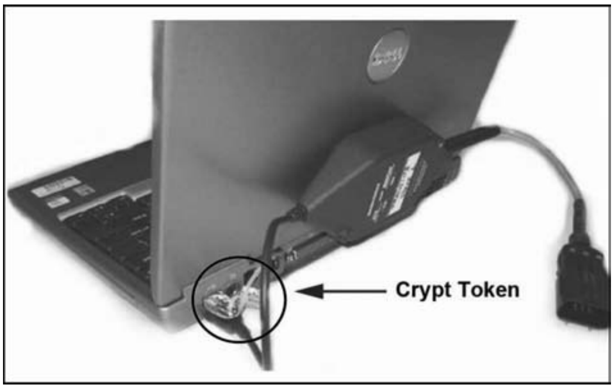


Figure 39. Crypt Token Installed on Laptop

Figure 40. Opening the Service Tool Display

Idle Mixture Adjustment

The CA100 mixer requires adjustment of the idle mixture screw to assure optimal emissions and performance. This adjustment accounts for minor part-to-part variations in the fuel system and assures stable performance of the engine at idle. Once adjusted, the idle mixture screw is sealed with a tamper proof cap, after which it need not be adjusted for the life of the vehicle.

Therefore, the only situations in which the idle mixture screw needs to be adjusted are when the engine is initially fitted with a fuel system at the factory and following the field replacement of the mixer. Under these situations, follow the procedures below for adjustment of the idle mixture screw.

Factory Test Preparation:

1. Install the MI-07 fuel system, wiring harness and SECM-48 control module on the engine.

2. All coolant hoses should be attached, filled with coolant and bled to remove any air.

3. Attach LPG fuel lines.

4. Attach wiring harness to battery power.

5. Attach exhaust system.

6. If present, set fuel select switch to LPG fuel.

When operated at the factory, it is critical to simulate the airflow found on a forklift at idle as nearly as possible in order to achieve the proper air valve lift in the mixer. It may be necessary to place a load on the engine to achieve the required airflow without overspeeding the engine. Means of achieving this load include:

a) Place an electrical load on the alternator. The alternator should be able to briefly hold loads of approximately 1.2 kW.

b) Attach the engine to a dynamometer.

Attach the Mototune Service Tool to the wiring harness and add parameter MAFPort to the display screen.

Factory Adjustment Procedure:

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

1. Operating the engine on LPG fuel, start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75 oC).
2. Adjust the load until MAFPort equals 3.3 to 3.5 g/sec.
3. Mototune display parameter LP Fuel Control must display “Closed Loop”.
4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.
6. Adjust the idle mixture screw on the mixer until a reading of 35-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 41). If engine idle performance is unstable, screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.

AFR CONTROL	LP	
LP Fuel Cntrl	Open-Loop	
Duty Cycle %	0.00	
LP Adapt Offset	0.00	
O2 Value	1.00	Phi
AFR CONTROL	Gasoline	
Gasoline Fuel Cntrl	Open-Loop	
O2 Value	1.00	Phi
Gasoline Adapt Factor	0.00000	
INJ 1 mg per Injection		

Closed Loop
Duty Cycle%

Figure 41. FTV Duty Cycle Percentage Displayed on Service Tool

7. Use the accelerator pedal to increase rpm above idle momentarily (rev the engine) then release the pedal to return to idle rpm. The duty cycle setting should remain within the adjustment range (35-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.
8. If the FTV duty cycle reading is above 55% adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (35-55%) and engine rpm is stable. DO NOT adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of 25-60% is acceptable if the optimum range of 35-55% cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below 60%, the mixer is faulty and should be replaced.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

9. Turn the ignition key to the OFF position to shut down the engine.
10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 42).

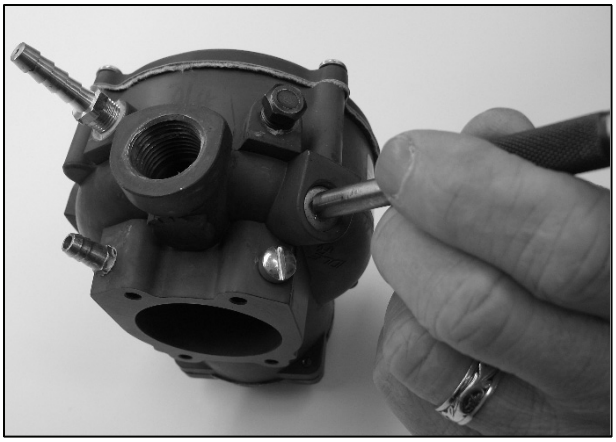
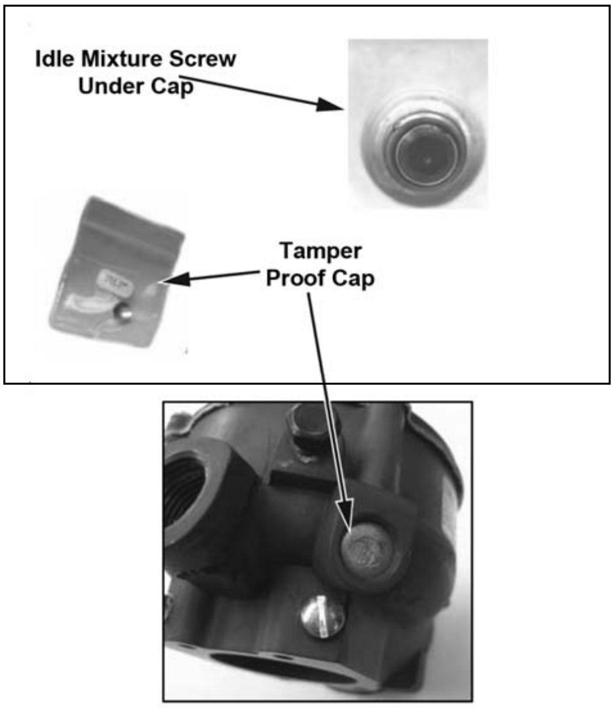


Figure 42. Installing Tamper Proof Cap



Field Adjustment Procedure:

The idle mixture adjustment should only be necessary on a new mixer that does not have the tamper proof cap installed. The method for making the idle mixture adjustment to a running engine is to use the Service Tool software by connecting a laptop computer to the SECM. If you do not have the Service Tool a multimeter capable of measuring duty cycle, such as a Fluke 87 III, can be used. If using a multimeter, connect the meter positive lead to between battery positive and the meter negative to the FTV signal wire. For the Fluke 87, press the “RANGE” button until 4 or 40 appears in the lower right-hand corner of the display. Press the “Hz” button twice so that the percent sign (%) appears on the right-hand side of the display. The multimeter will then read the duty cycle percentage the same as the Service Tool shown in Figure 41.

1. After installing a new mixer, operate the engine Bon LPG fuel. Start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75 oC).

2. Place the transmission in Neutral.

3. Mototune display parameter LP Fuel Control must display “Closed Loop”.

4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.

5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.

6. Adjust the idle mixture screw on the mixer until a reading of 35-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 41). If engine idle performance is unstable screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.

7. Use the accelerator pedal to increase rpm above idle momentarily (rev the engine) then release the pedal to return to idle rpm. The duty cycle setting should remain within the adjustment range (35-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.

8. If the FTV duty cycle reading is above 55% adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (35-55%). DO NOT adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of 25-60% is acceptable if the optimum range of 35-55% cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below 60%, the mixer is faulty and should be replaced.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

9. Turn the ignition key to the OFF position to shut down the engine.

10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 42).

Parts Description

CA100 Mixer for G420FE Engine

Parts List of CA100 Mixer (Certified)

REF NO	DESCRIPTION	QTY
1	Torx Screws (T-25) #10-24 x 5/8”	4
2	Lockwashers (T-210) #10 SST	4
3	Mixer Cover	1
4	Mixer Spring	1
5	Diaphragm	1
6	Air Valve Assembly	1
7	Gas Valve Cone (part of air valve assembly)	1
8	Mixer Body	1
9	Expansion Plug Cap Ø 1/2” x 1/16” thick (Ø 12.7mm x 27mm)	1
10	Fuel Inlet	1
11	Air Horn Gasket	1
12	Air Horn Adapter 2-1/16” (52.37mm)	1
13	Fillister Head Screws SEMS Lockwasher 10-24 UNC x 5/8”	4
14	Throttle Body Gasket	1
15	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	4

Exploded View of CA100 Mixer (Certified)

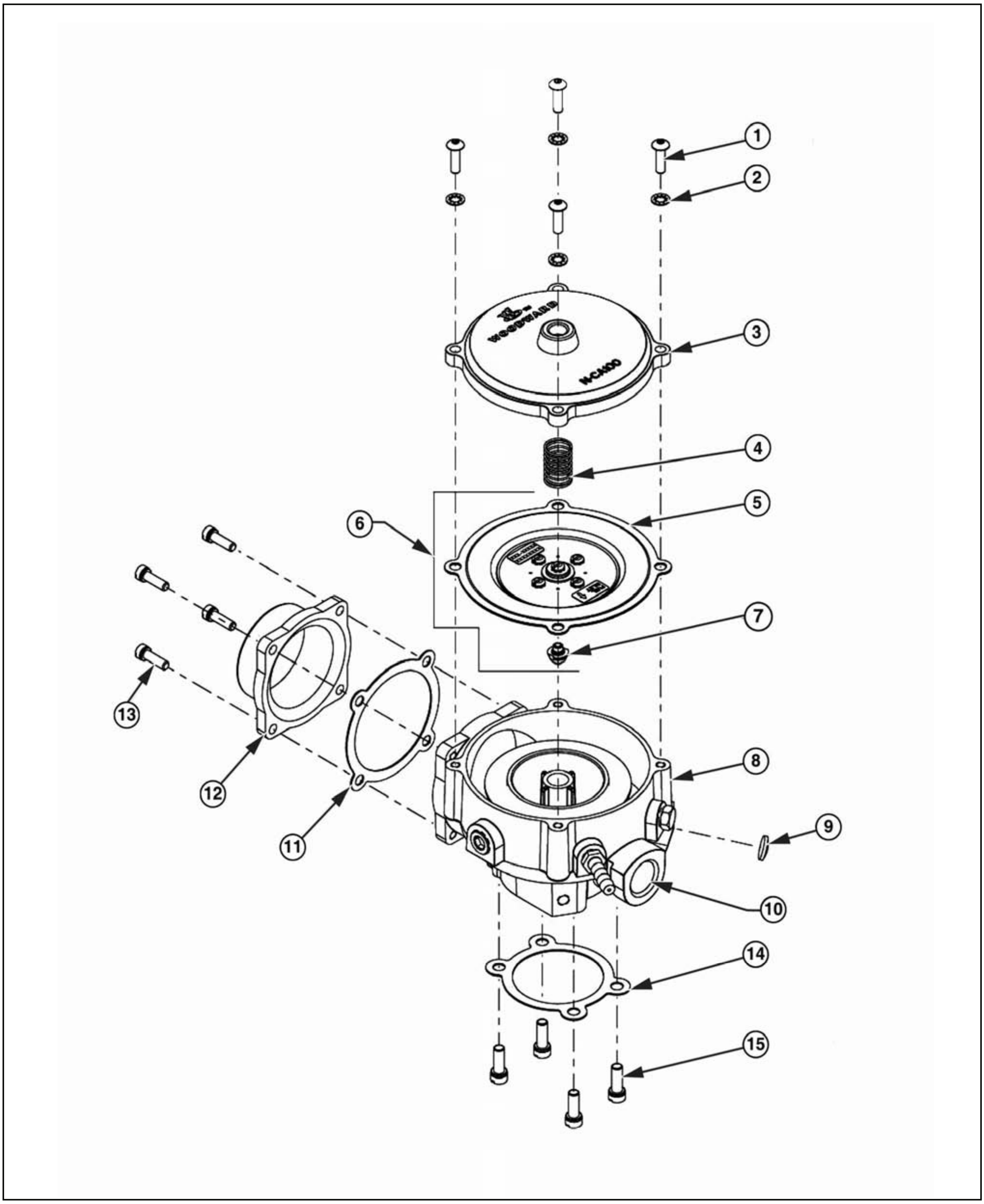


Figure 44. CA100 Certified Mixer Exploded View

N-2007 Regulator for G420FE Engine

Parts List of N-2007 Regulator (Certified)

REF NO	DESCRIPTION	QTY
1	N-2007 Body	1
2	Diaphragm, Primary Assembly	1
3	Springs, Primary Assembly	2
4	Cover, Primary Assembly	1
5	Spring, Secondary Seat, Red	1
6	Dowel Pin Ø 0.094” x 1” L (Ø 2.39mm x 25.4mm L) Hardened Steel	1
7	Diaphragm, Secondary Assembly	1
8	Lever, Secondary	1
9	Seat, Secondary	1
10	Valve Primary	1
11	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	6
12	Pan Head Screw SEMS Ext. Tooth Lockwasher #12-24 x 1/4”	1
13	Body Gasket	1
14	Back Plate	1
15	O-ring, Size 107 GLT Viton®	1
16	Bottom Plate Gasket	1
17	Plate Cover	1
18	Fillister Head Screws SEMS Split Lockwasher #12-24 x 1-3/8”	6
19	Hex Head Screws SEMS Split Lockwasher 1/4-20 x 5/8”	4
20	Plug, Socket Head Pipe (T-086)	1
21	Cover, Secondary Diaphragm	1
22	Lockwasher, Int. Tooth (T-210) #8 SST	6
23	Torx Screws (T-15) #8-32 x 5/8”	6

Exploded View of N-2007 Regulator (Certified)

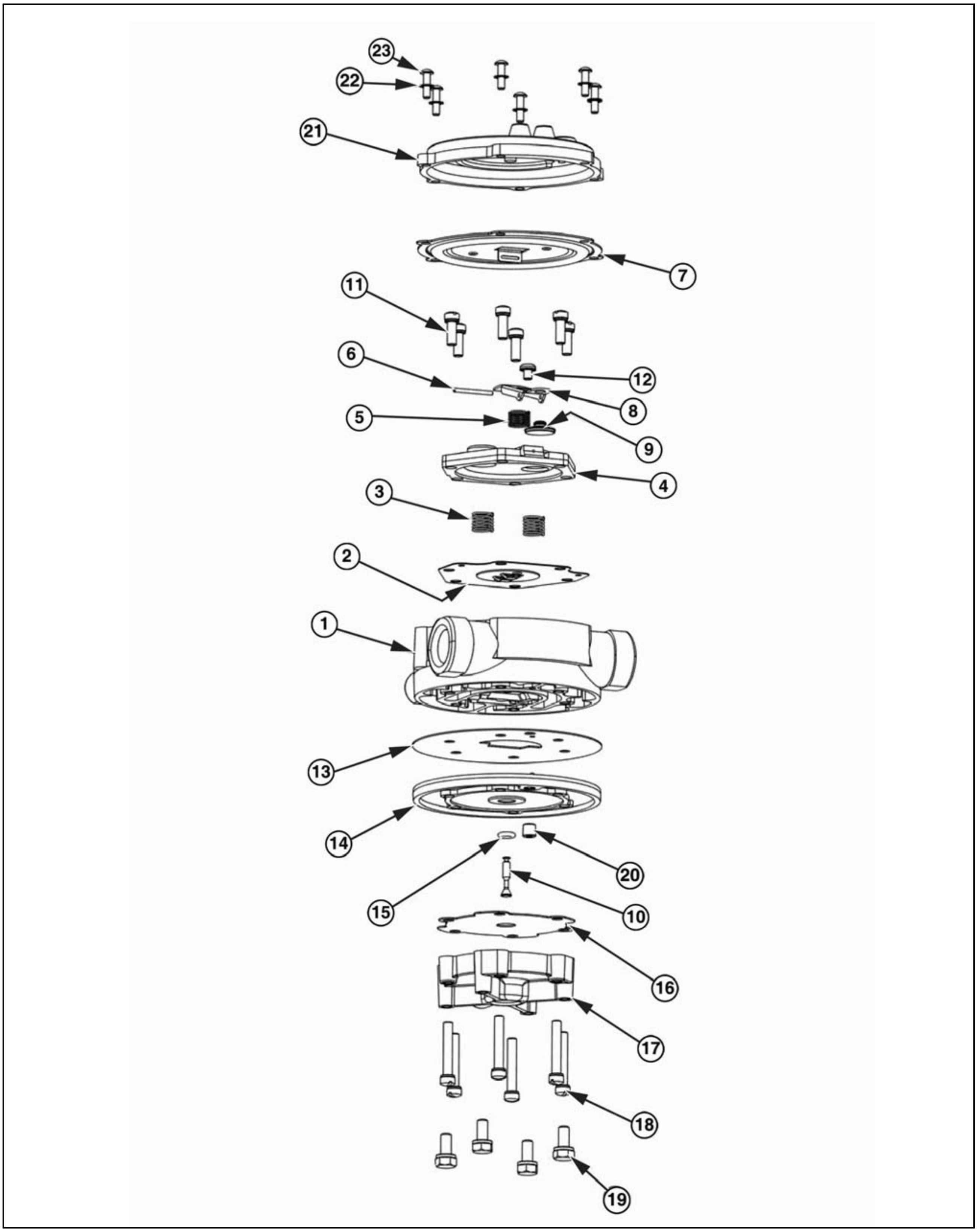


Figure 46. N-2007 Certified Regulator Exploded View

G420F LPG System Inspection and Repair

Removal and Installation

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

G420F Fuel System Connections

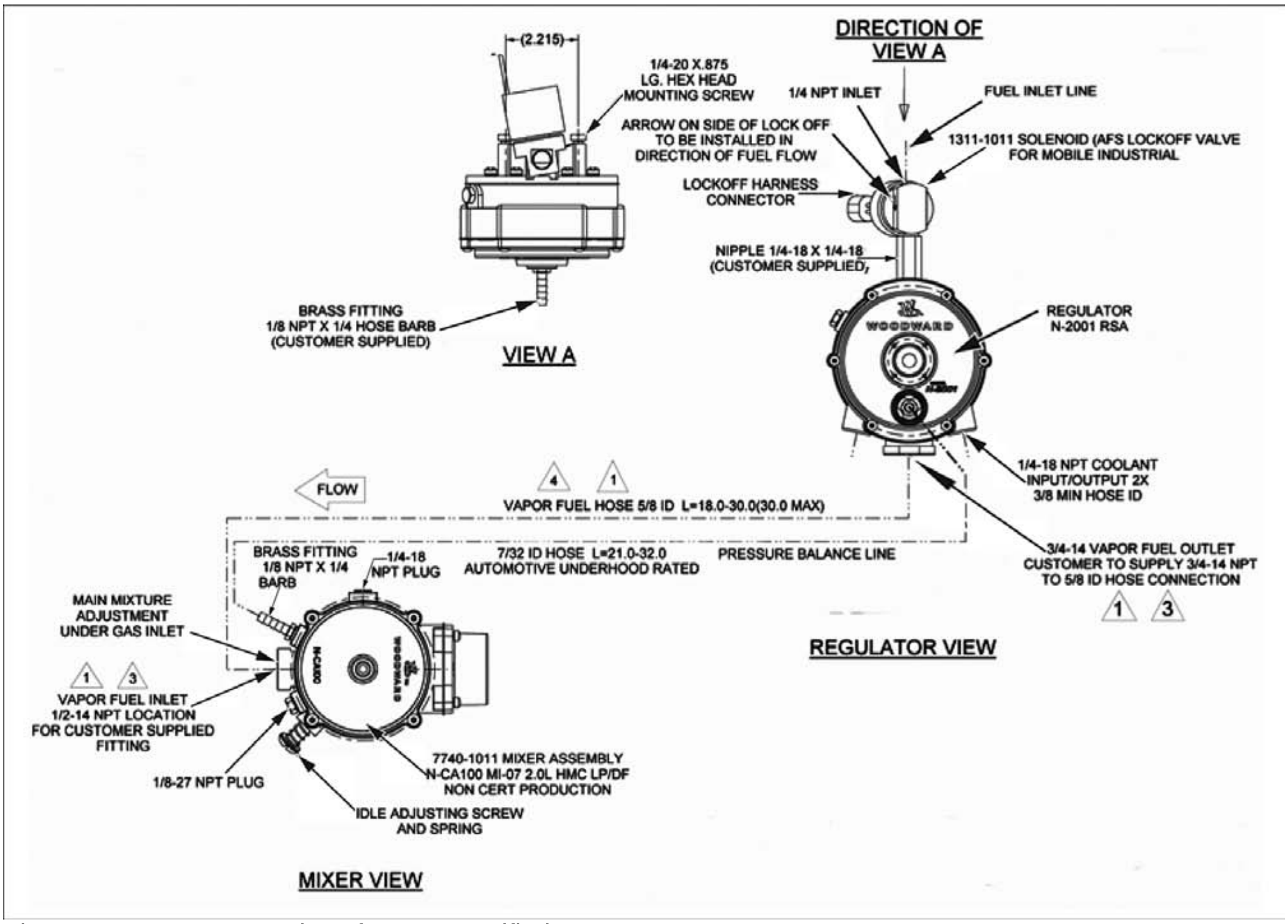


Figure 27. Hose Connections for Non-Certified Systems

DIAGRAM NOTES

1 Only one 90 fitting permissible on vapor fuel line between mixer and regulator

3 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.46” (11.68mm)

4 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

5 Fuel outlet must be positioned vertically in the down position

NOTE: Preferred mounting of regulator is off engine

Removal and Installation of N-2001 LP Regulator/Converter

Follow the procedures below for removal and reinstallation of the N-2001 regulator.

N-2001 Removal Steps

Refer to **Figure 29.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Remove the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

4. Remove the two rear-mounting bolts that hold the regulator to the support bracket. This will permit easier access to the remaining hose clamps.

5. Remove the two cooling lines (4) from the regulator.

NOTE: It will be necessary to either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

6. Remove the fuel vapor outlet hose (5) from the regulator.

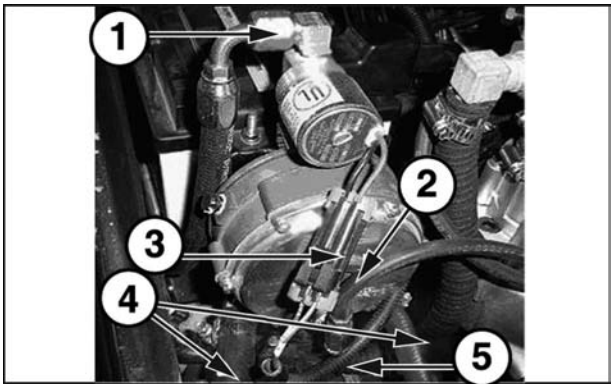


Figure 29. N-2001 Regulator in Non-Certified System

N-2001 Installation Steps

Refer to **Figure 29.**

1. Install the fuel vapor outlet hose (5) from the regulator.

2. Install the two cooling lines (4) from the regulator.

3. Install the two rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 50-60 lbf-in (5.65-6.78 N-m)

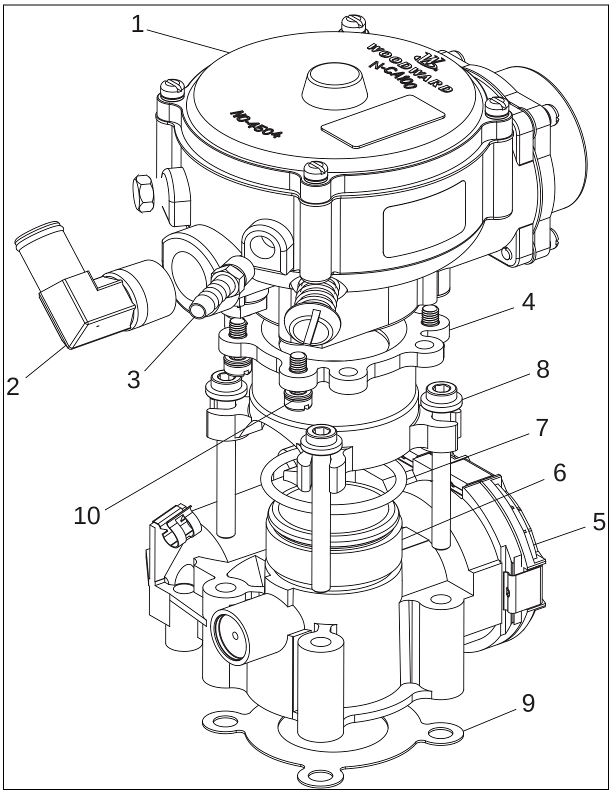
4. Install the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

5. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G420F

Follow the procedures below for removal and reinstallation of the CA100 mixer in non-certified systems.

CA100 Mixer Removal Steps



1. Mixer-Non Cert
2. Fitting-To Regulator
3. Fitting-To Regulator
4. Apollo Adapter-ITB, Mixer
5. ITB
6. O-Ring Spacer
7. O-Ring
8. Bolt-ITB.Conn
9. Gasket-ITB
10. Bolt

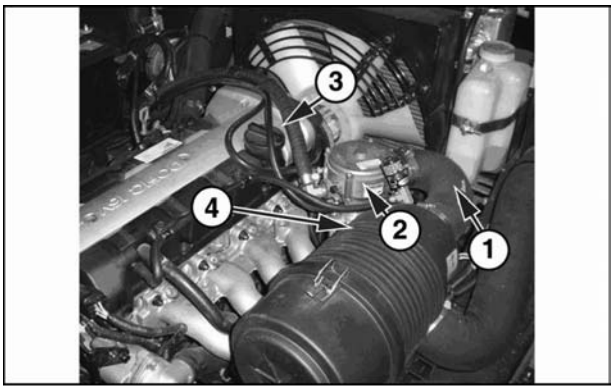


Figure 33. CA100 Mixer in Non-Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in "OFF" position.

4. Remove the air cleaner hose (1).

5. Remove the vacuum line (2).

6. Remove the vapor fuel inlet line from the mixer (3).

7. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector.

8. Loosen the four bolts that secure the mixer /adapter/throttle body assembly to the intake manifold.

9. Remove the mixer (3) and the throttle body (**4**) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

10. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

11. Remove the four mounting screws that attach the throttle adapter to the mixer.

12. Remove the vapor fuel inlet fitting from the mixer.

CA100 Mixer Installation Steps

1. Install the vapor fuel inlet fitting onto the mixer.

2. Install the four mounting screws that attach the throttle adapter to the mixer. (See **Figure 32)**. Torque bolts to 30-40 lbf-in (3.39-4.52 N-m).

3. Position the mixer/adapter assembly onto the throttle body (4), then drop in the four mounting bolts and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring.

4. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.

5. Connect the wiring harness to the throttle body.

6. Install the vapor fuel inlet line to the mixer.

7. Install the vacuum line (**2**) to the mixer.

8. Install the air cleaner hose (**1**).

⚠ CAUTION

The 1/8” NPT x 1/4” hose barb fitting that is installed in the mixer housing uses a specific machined orifice size through the fitting. This orifice fitting is part of the mixer assembly and is an integral part of the MI-07 control. If this fitting is damaged the mixer will need to be replaced. DO NOT replace this fitting with a standard hose barb fitting or use a drill bit to clean out the fitting passage way.

NOTE : A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

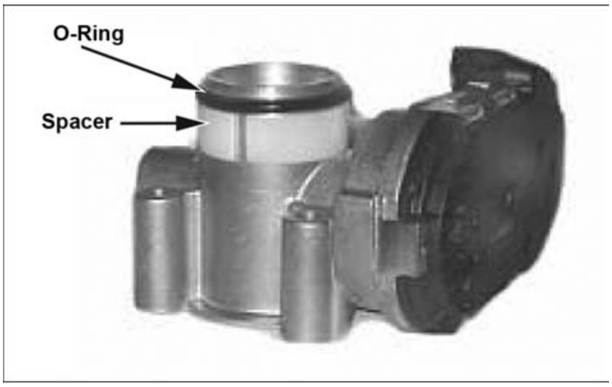


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

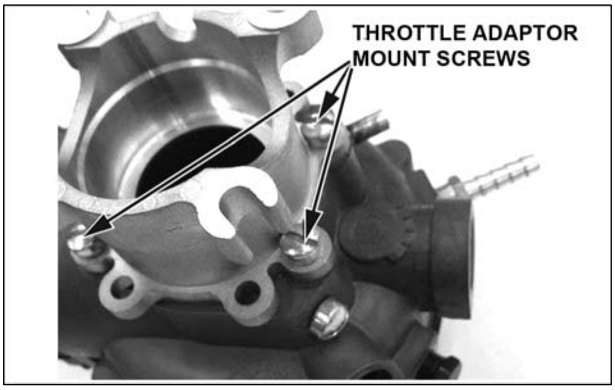


Figure 32. Throttle Adapter Mount Screws

Tests and Adjustments

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

N-2001 Regulator Service Testing

For checking the N-2001 regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the N-2001). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb

3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb

4. Vacuum hose

5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 30). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the N-2001 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-1.2 “ WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

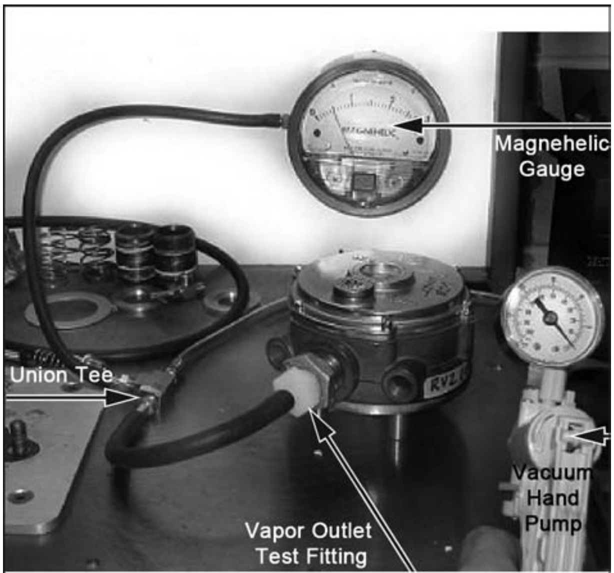


Figure 30. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Hand vacuum pump

2. Regulator fuel inlet test fitting 1/4 NPT standard air coupling)

3. Test gauge fitting (1/4" NPT X 1/4" hose b)

4. Vacuum hose or vinyl tubing

5. 0-60" WC Magnehelic gauge (inches of water column)

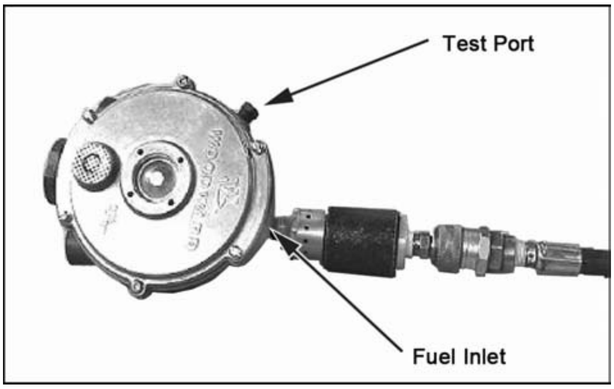


Figure 31. Primary Stage Test Connection

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16" NPT hose barb fitting (Figure 31).

2. Connect a compressed air line (shop air ~100 psi) to the liquid propane fuel inlet of the N-2001 regulator (Figure 31).

Figure 32. Magnehelic Gauge Connection to Hose Barb

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 32) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60" WC on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2001 regulator.

NOTE : The N-2001 primary stage pressure can also be tested at idle on a running engine. The N-2001 primary pressure should be between 40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 rpm, idle.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4” (6.35mm) NPT with three 1/4” (6.35mm) NPT x 1/4” (6.35mm) hose barbs
2. Vacuum hose
3. 0-20” H2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5” and 8” H2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

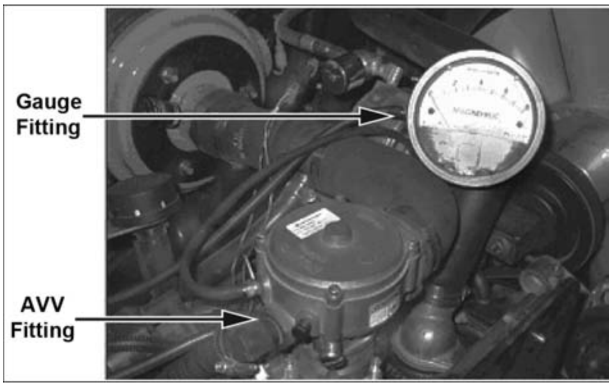


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.

Connection of the MI-07 Service Tool

To use the Service Tool, a USB (Universal Serial Bus) to CAN (Controller Area Network) communication adapter by KVaser will be required along with a Crypt Token (Figure 38). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (Figure 39).

2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. (*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).

3. Connect a timing light to the engine.

4. Turn the ignition key to the ON position (Do Not Start the Engine).

5. Launch the MotoView program on your computer and open the Service Tool display (Figure 40).

Figure 38. KVaser Communication Adapter

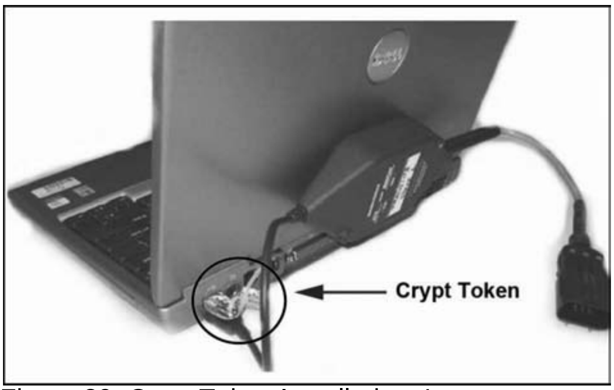


Figure 39. Crypt Token Installed on Laptop

Figure 40. Opening the Service Tool Display

Idle Mixture Adjustment

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

G420F LP Fuel Systems With O2 Sensor

Idle Adjustment

1. Install mixer and a UEGO or HEGO sensor. (A UEGO sensor should be used when desired phi settings are not at stoichiometric.)

2. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

3. Allow the engine to reach steady state at idle.

4. While monitoring the output of the UEGO or HEGO sensor adjust the idle screw using a standard screwdriver until the desired phi reading is achieved (phi = 1.00 to 1.01 is optimal). To make the mixture richer, turn the screw clockwise; to make the mixture leaner, turn the screw counter-clockwise.

5. Rev the engine to take it off of idle and let it return to idle.

6. Once the engine has reached steady state at idle, verify the phi reading. Adjust further as needed.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Monitor the output of the UEGO or HEGO sensor while the engine is at the higher speed with the load applied (phi = 1.00 to 1.05 is optimal).

4. If the phi reading is not at the desired level, bring the engine back to idle and adjust the power valve.

5. Bring the engine back to the higher speed with a load applied and verify the power valve setting. Adjust further as needed.

6. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

G420F LP Fuel Systems Without O2 Sensor

Idle Adjustment

1. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

2. Allow the engine to reach steady state at idle.

3. With the idle screw completely tightened clockwise, use a standard screwdriver to adjust the idle screw counterclockwise until a minimum average MAP value has been reached. The MAP value is displayed on the Service Tool screen.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.
The power valve should be adjusted to obtain maximum torque converter stall speed.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

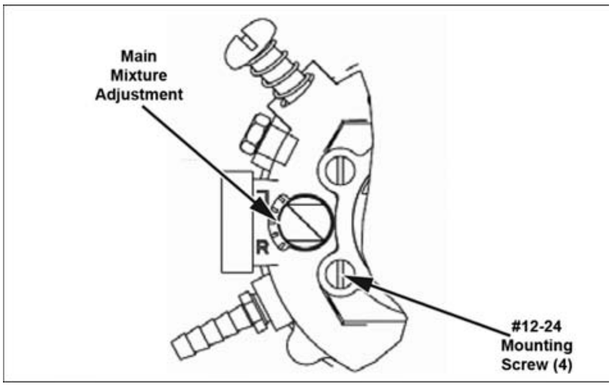


Figure 43. Main Mixture Adjustment on Bottom of Mixer (partial view)

Parts Description

CA100 Mixer for G420F Engine

Refer to **Figure 45** exploded view on facing page.

REF NO.	DESCRIPTION	QTY
1	Screws 10-24 x 5/8” SEMS	4
2	Mixer Cover	1
3	Air Valve Spring	1
4	Screws 6-32 x 1/4” SEMS	5
5	Plate Backup	1
6	Diaphragm, Silicone	1
7	Air Valve Ring	1
8	Air Valve Assembly	1
9	Idle Screw 3/8-16 x 1-1/4”	1
10	Idle Screw Spring	1
11	Plugs, 1/8” Pipe Hex Head	2
12	Mixer Body Assembly	1
13	Screws, 1/4-28 x 5/16”	2
14	Plug, 1/4” Pipe	1
15	Screws 10-24 x 5/8” SEMS	4
16	Air Horn	1
17	Air Horn Gasket	1
18	Throttle Body to Mixer Gasket	1

Parts List for CA100 Mixer

Exploded View

CA100 Mixer

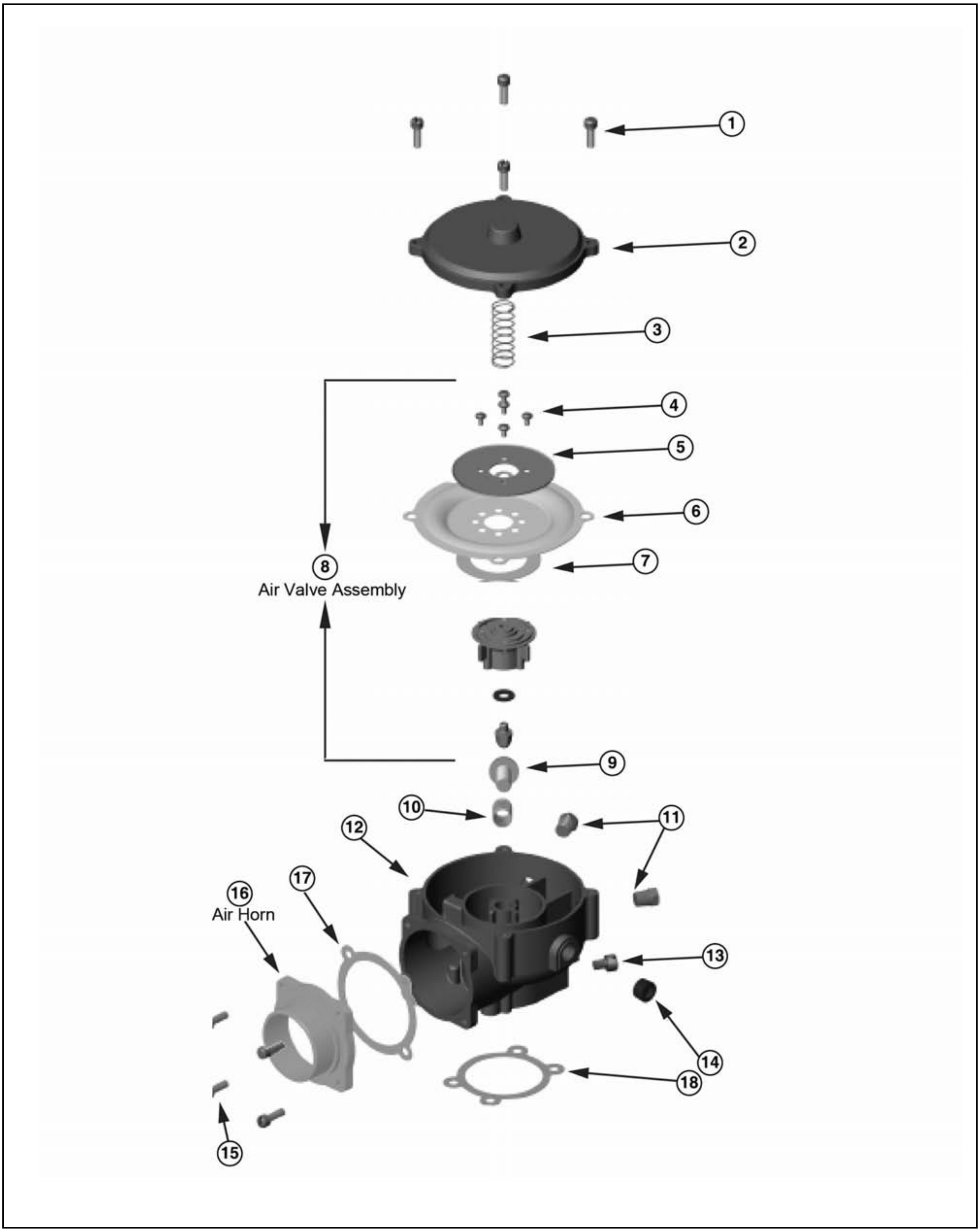
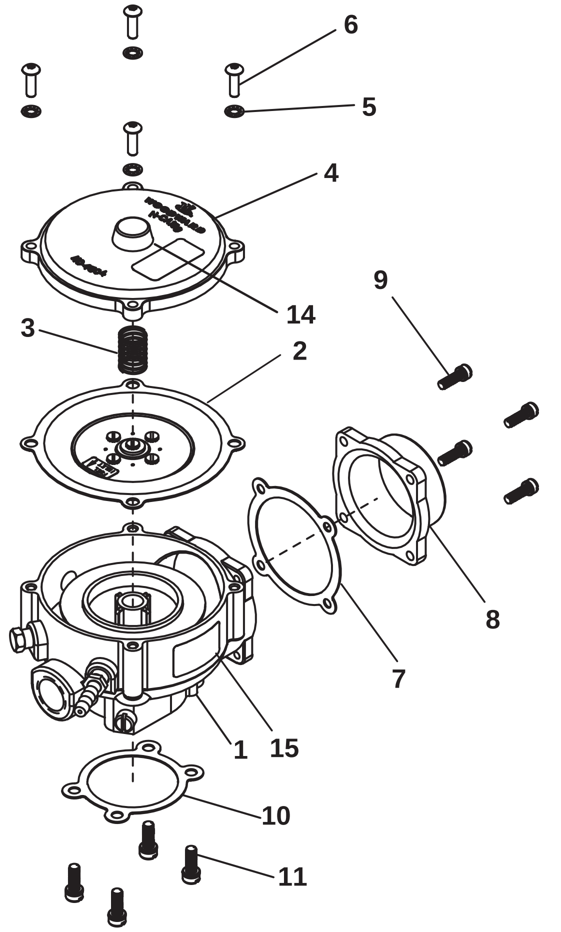


Figure 45. CA100 Non-Certified Mixer Exploded View

CA100 Disassembly and Service



(1) BODY (2) VALVE (3) SPRING (4) COVER
(5) WASHER (6) SCREW (7) GASKET (8) ADAPTER
(9) SCREW (10)GASKET (11) SCREW

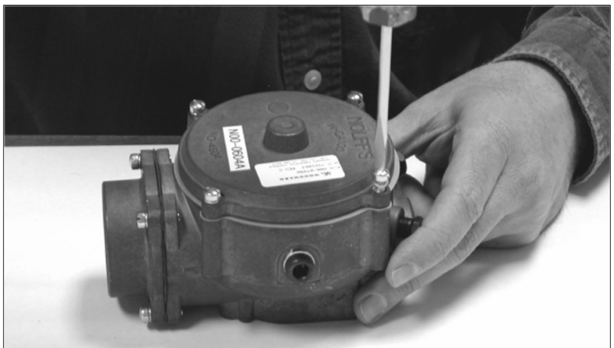


Figure M4

1. With the mixer/adapter assembly removed from the engine, and the throttle adapter removed from the mixer, remove the four cover retaining screws from the top of the mixer (Figure M4).


Figure M5

2. Gently remove the diaphragm cover from the top of the mixer. Take care not to loose the air-valve spring shown in (Figure M5).

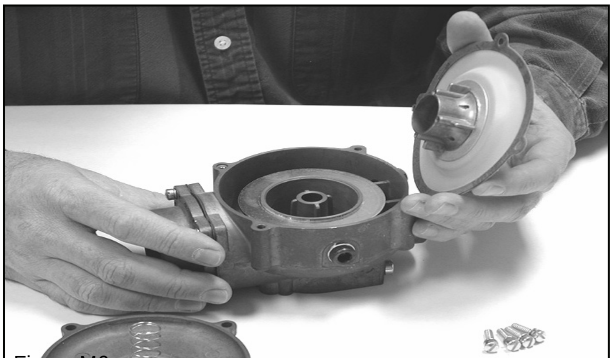


Figure M6

3. Remove the air-valve assembly from the mixer as shown in (Figure M6).

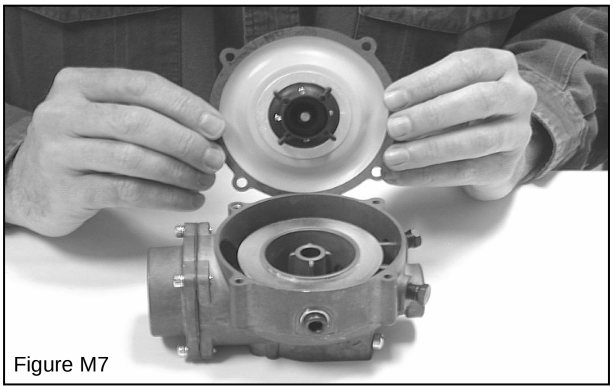


Figure M7

4. Clean the heavy end deposits from the mixer body with solvent. Be sure the mixer body is completely dry before installing the new air-valve assembly. Replace the air-valve assembly as shown (Figure M7).

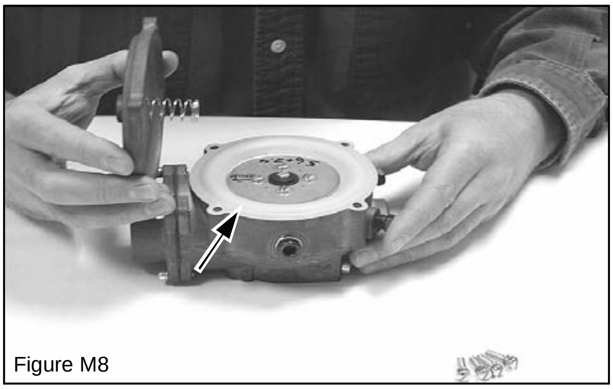


Figure M8

5. Place the alignment mark on top of the air valve assembly toward the fuel inlet of the mixer; this places the small notches in the fuel metering valve (fuel cone) inline with the fuel inlet and the large notches of the fuel metering valve "cone", perpendicular to the fuel inlet of the mixer. Now reinstall the air-valve spring and diaphragm cover (Figure M8).

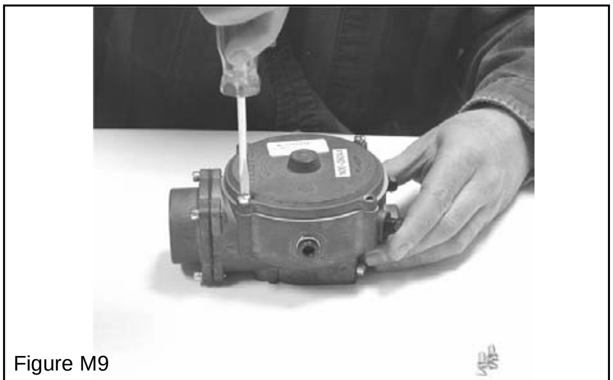


Figure M9

6. Tighten the cover fastners and reinstall the mixer on the engine (Figure M9).

CAUTION
The 1/8" NPT X ¼" hose barb fitting that is installed in the mixer housing uses a specific machined orifice size through the fitting. This orifice fitting is part of the mixer assembly and an integral part of the MI-04 control. DO NOT replace this fitting with a standard hose barb fitting or use a drill bit to clean out the fitting passage way. If this fitting is damaged the mixer will need to be replaced.

CA100 Disassembled Service

1. Clean the air valve assembly with soap and warm water to remove heavy-end deposits. Inspect the fuel metering valve and sealing ring for wear. Replace worn components as necessary.

Replace all gaskets before assembly.

Clean the mixer body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent. Make sure all parts are completely dry before re-assembly.

NOTE
For re-assembly of the CA100 reverse the disassembly steps.

WARNING
DO NOT spray car carburetor cleaner or solvent into the mixer while installed on the engine. These chemicals may damage the oxygen sensor and cause pre-mature failure of the catalytic muffler.

N-2001 Regulator for G420F Engine

Refer to Figure 47 exploded view on facing page.

Parts List
N-2001-RSA Regulator

REF NO.	DESCRIPTION	QTY
1	Cover Screws 8-32 x 5/8” SEMS	4
2	Torx Screws (T-15) 8-32 x 5/8” Tamper Resistant	2
3	Lockwasher #8 Internal Tooth	2
4	Secondary Cover	1
5	Secondary Diaphragm Assembly	1
6	Pan Head Screw 10-24 x 1/4” w/Star Washer	1
7	Secondary Lever	1
8	Secondary Valve	1
9	Secondary Lever Fulcrum Pin	1
10	Red Secondary Spring	1
11	Pilot Valve Lever	1
12	Pilot Valve Lever Fulcrum Pin	1
13	Internal Hex Head Set Screw 8-32 x 1/4”	1
14	Cover Screws 12-24 x 5/8” SEMS	6
15	Primary Diaphragm Cover	1
16	Primary Regulator Springs	2
17	Primary Diaphragm Assembly	1
18	1/8 NPT Hex Pipe Plug Fitting	1
19	Body Assembly	1
20	Body Seal O-ring	1
21	Body Gasket	1
22	Regulator Back Plate	1
23	Primary Seal O-Ring	1
24	Primary Regulator Valve	1
25	Cover Screws 12-24 x 5/8” SEMS	6
26	Inlet Seal O-Ring	1
27	Inlet Plug	1
28	Hex Head Screws 1/4-20 UNC-2A x 5/8” SEMS	2

Exploded View
N-2001-RSA Regulator

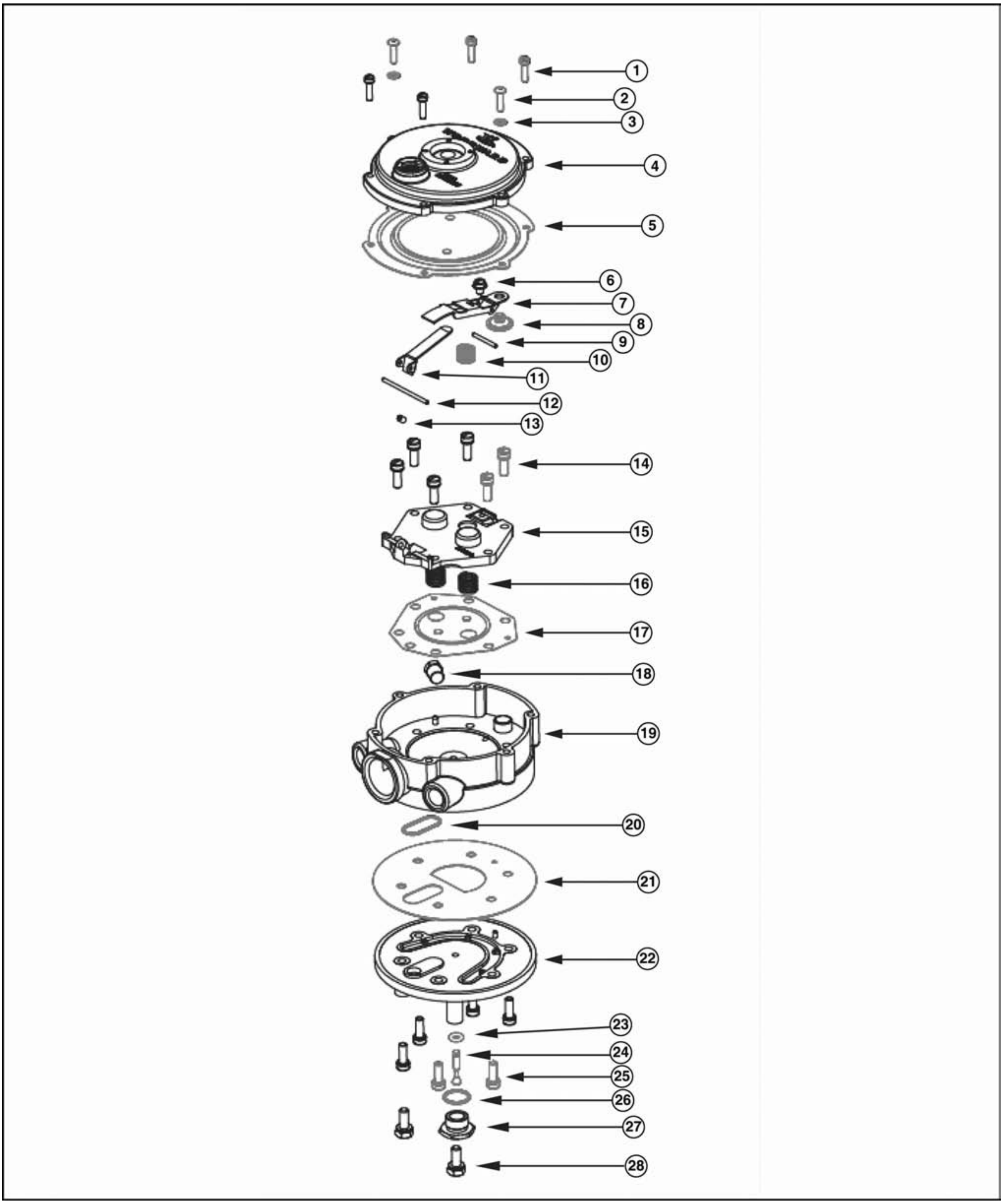


Figure 47. N-2001 Regulator Exploded View

N2001 Regulator Disassembly Steps:

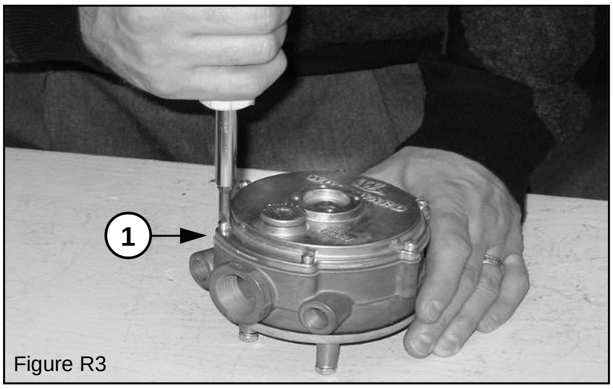


Figure R3

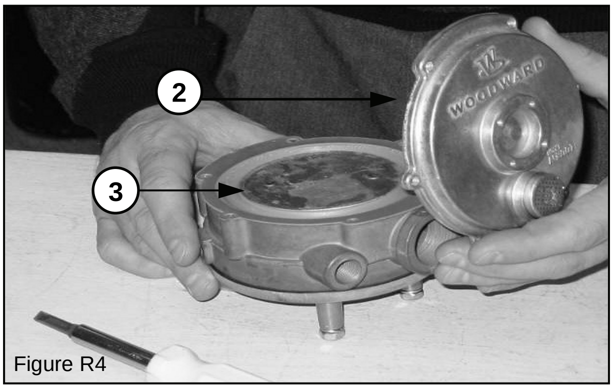


Figure R4

1. Remove the six secondary cover screws (1), the secondary cover (2) and the secondary diaphragm (3).

2. Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).

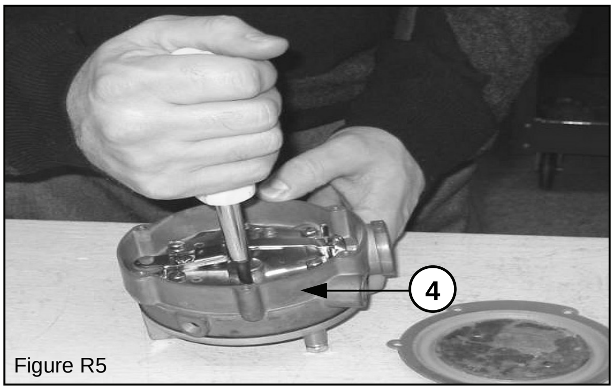


Figure R5

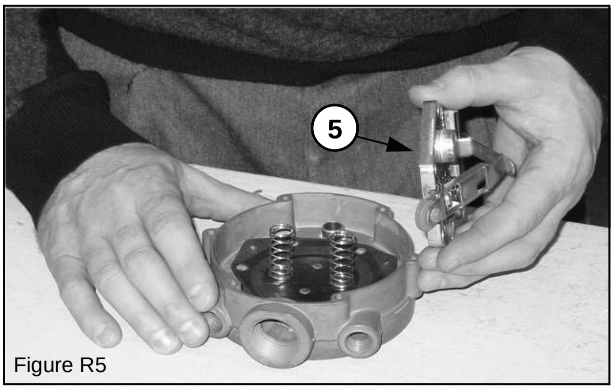


Figure R5

Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).

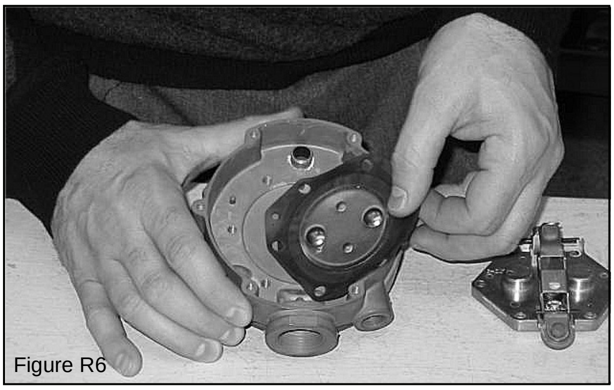


Figure R6

Remove the primary diaphragm by sliding the diaphragm to one side, releasing the primary valve pin (Figure R6).

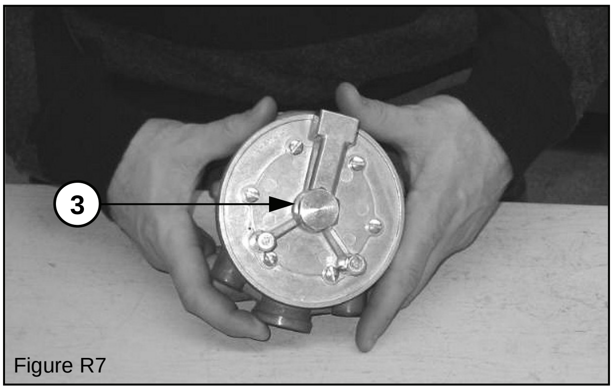


Figure R7

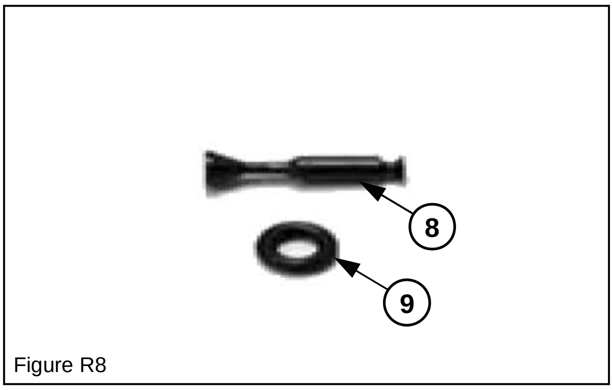


Figure R8

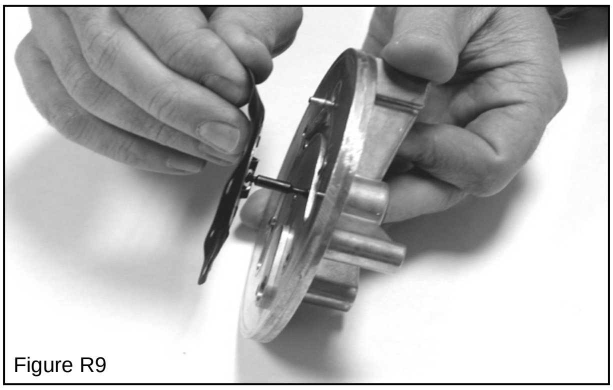
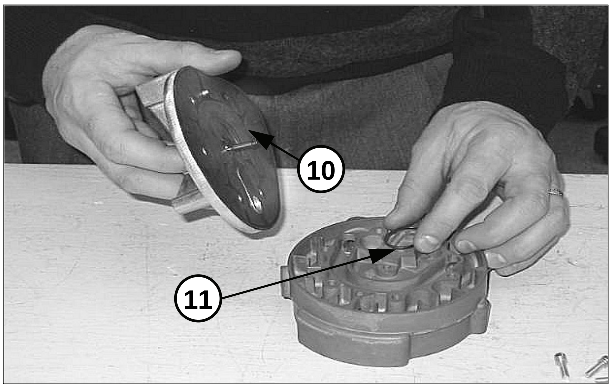


Figure R9

Turn the regulator body over with the rear fuel inlet plate facing up. Remove the primary valve access plug (7), the primary valve (8) and the primary valve o-ring seal (9). ***The primary valve goes through the inlet plate, then through the body assembly and is retained by the primary diaphragm (Figure R9).***



6. Remove the body gasket (10), body o-ring seal (11) and the fuel inlet plate, exposing the fuel inlet expansion chamber and the coolant passage.

NOTE
For re-assembly of the N2001 regulator/converter, reverse the steps for disassembly. Tighten all fasteners to recommended torque values and test the regulator before installing in the vehicle. Torque primary cover screws to (40-50 inch lbs.), secondary cover screws to (15-18 inch lbs.).

N2001 Disassembled Service

1. Clean the primary and secondary valves with soap and warm water to remove heavy-end deposits. Inspect the valve seats and o-rings for wear. Replace worn components as necessary.

2. Clean the primary and secondary diaphragms with soap and warm water. Inspect for wear, tears or pinholes and deformations that may cause leaks or poor performance of the regulator/converter.

3. Replace the body gasket of the coolant chamber and body o-ring seal when servicing the N2001 to avoid coolant leaks from the fuel expansion chamber to the coolant passage.

4. Clean the regulator body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent.

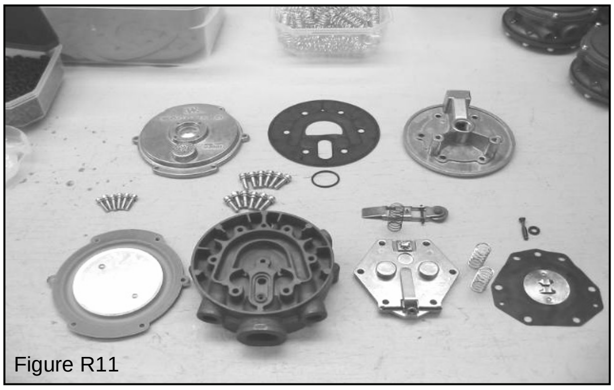


Figure R11

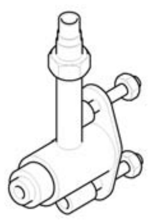
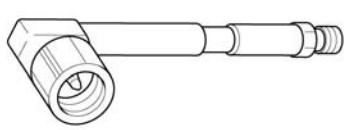
5. Make sure all parts (Figure R11) are completely dry before re-assembly.

Chapter 7. MPI GASOLINE FUEL DELIVERY SYSTEM

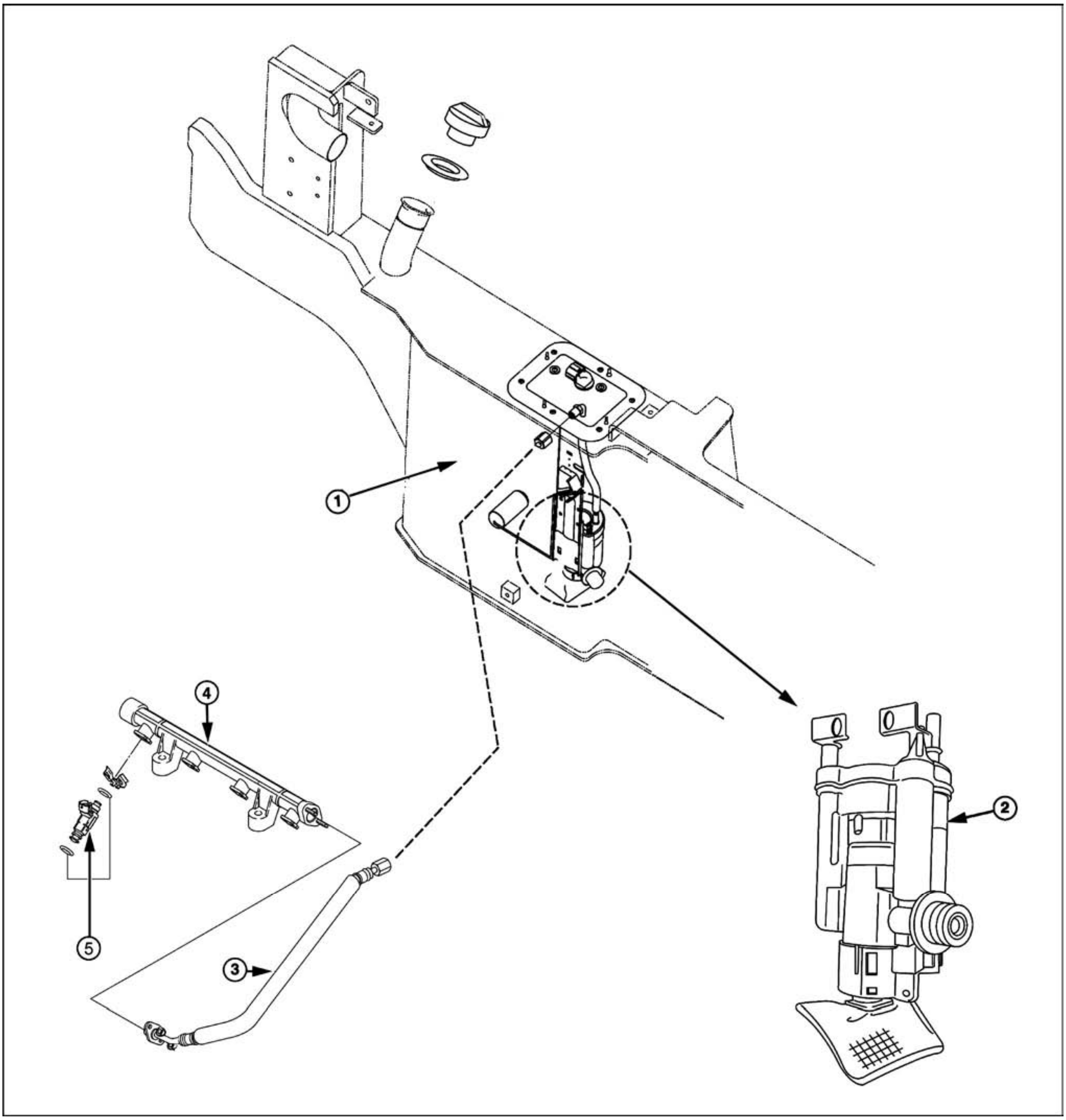
Specification

Items	Specification	
Fuel Retrun System	Type	Returnless
Fuel Filter	Type	High pressure type (built in Fuel Pump Assembly)
Fuel Pressure Regulator	Type	Built in fuel pump assembly
	Regulated Fuel Pressure	350 kpa (3.5kg/cm2, 49.8psi)
Fuel Pump	Type	Electrical, in-tank type

Special Tools

Tool (Numberandname)	Illustration	Application
09353-24100 FuelPressureGauge	 EFDA003A	Measuring the fuel line pressure
09353-38000 Fuel Pressure Gage Adapter	 BF1A025D	Connection between the delivery pipe and fuel feed line
09353-24000 Fuel Pressure Gage Connector	 EFDA003C	Connection between Fuel Pressure Gage (09353-24100) and Fuel Pressure Gage Adapter (09353-38000)

Components Location



1. Fuel Tank
2. Fuel Pump (Including full pressure regulator and fuel filter)
3. Fuel Hose Assy
4. Fuel Rail
5. Injector

Fuel Pressure Test

Release The Internal Pressure

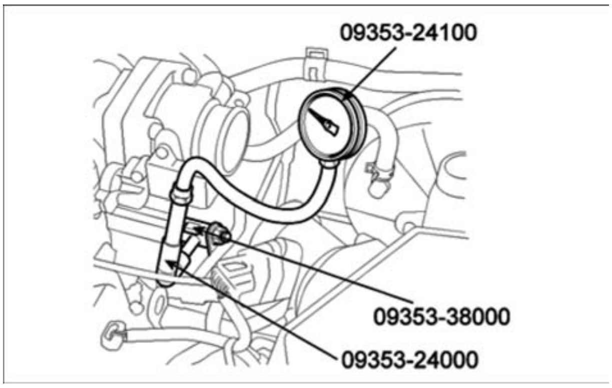
1. Disconnect the fuel pump connector.

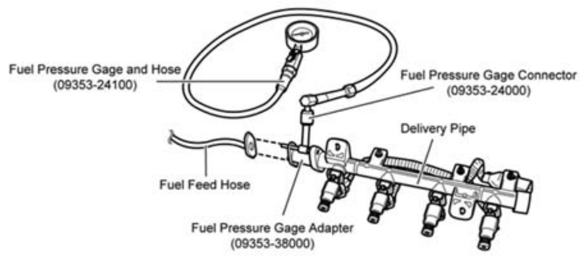
2. Start the engine and wait until fuel in fuel line is exhausted.

3. After the engine stalls, turn the ignition switch to OFF position
and diconnect the negative (-) terminal from the battery.

NOTE: Be sure to reduce the fuel pressure before disconnecting the fuel feed hose, otherwise fuel will spill out.

Install The Special Service Tool (SST) For Measuring The Fuel Pressure





1. Disconnect the fuel feed hose from the delivery pipe.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

2. Install the Fuel Pressure Gage Adapter (09353-38000) between the delivery pipe and the fuel feed hose.

3. Connect the Fuel Pressure Gage Connector (09353-24000) to the Fuel Pressure Gage Adapter (09353-38000).

4. Connect the Fuel Pressure Gage and Hose (09353-24100) to Fuel Pressure Gage Connector (09353-24000).

5. Connect the fuel feed hose to the Fuel Pressure Gage Adapter (09353-38000).

Inspect Fuel Leakage On Connection

1. Connect the battery negative (-) terminal.

2. Apply battery voltage to the fuel pump terminal and activate the fuel pump. With fuel pressure applied, check that there is no fuel leakage from the fuel pressure gauge or connection part.

Fuel Presure Test

1. Diconnect the negative (-) terminal from the battery.

2. Connect the fuel pump connector.

3. Connect the battery negative (-) terminal.

4. Start the engine and measure the fuel pressure at idle.

Standard Value: 350 kpa (3.5 kg/, 49.8 psi)

• If the measured fuel pressure differs from the standard value, perform the necessary repairs

Condition	Probable Cause	Supected Area
Fuel Pressure too low	Clogged fuel filter	Fuel filter
	Fuel leak on the fuel-pressure regulator that is assembled on fuel pump because of poor seating of the fuel-pressure regulator.	Fuel Pressure Regulator
Fuel Pressure too High	Sticking fuel pressure regulator	Fuel Pressure Regulator

5. Stop the engine and check for a change in the fuel pressure gauge reading.

After engine stops, the gage reading should hold for about 5 minutes

• Observing the declination of the fuel pressure when the gage reading drops and perform the necessary repairs using the table below.

Condition	Probable Cause	Supected Area
Fuel pressure drops slowly after engine is stopped	Injector leak	Injector
Fuel pressure drops immediately after engine is stopped	The check valve within the fuel pump is open	Fuel Pump

Release The Internal Pressure

1. Disconnect the fuel pump connector.

2. Start the engine and wait until fuel in fuel line is exhausted.

3. After the engine stalls, turn the ignition switch to OFF position and diconnect the negative (-) terminal from the battery.

NOTE: Be sure to reduce the fuel pressure before disconnecting the fuel feed hose, otherwise fuel will spill out.

Remove The Special Service Tool (SST) And Connect the Fuel Line

1. Disconnect the Fuel Pressure Gage and Hose (09353-24100) from the Fuel Pressure Gage Connector (09353-24000).

2. Disconnect the Fuel Pressure Gage Connector (09353-24000) from the Fuel Pressure Gage Adapter (09353-38000).

3. Disconnect the fuel feed hose from the Fuel Pressure Gage Adapter (09353-38000).

4. Disconnect the Fuel Pressure Gage Adapter (09353-38000) from the delivery pipe.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

5. Conenct the fuel feed hose to the delivery pipe.

Inspect Fuel Leakage On Connection

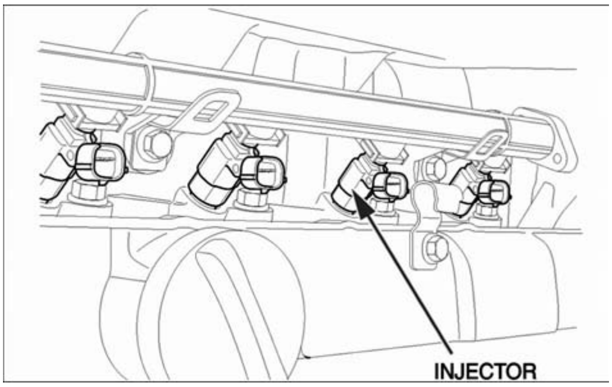
1. Connect the battery negative (-) terminal.

2. Apply battery voltage to the fuel pump terminal and activate the fuel pump. With fuel pressure applied, check that there is no fuel leakage from the fuel pressure gauge or connection part.

3. If the vehicle is normal, connect the fuel pump connector.

Injector

Component Location



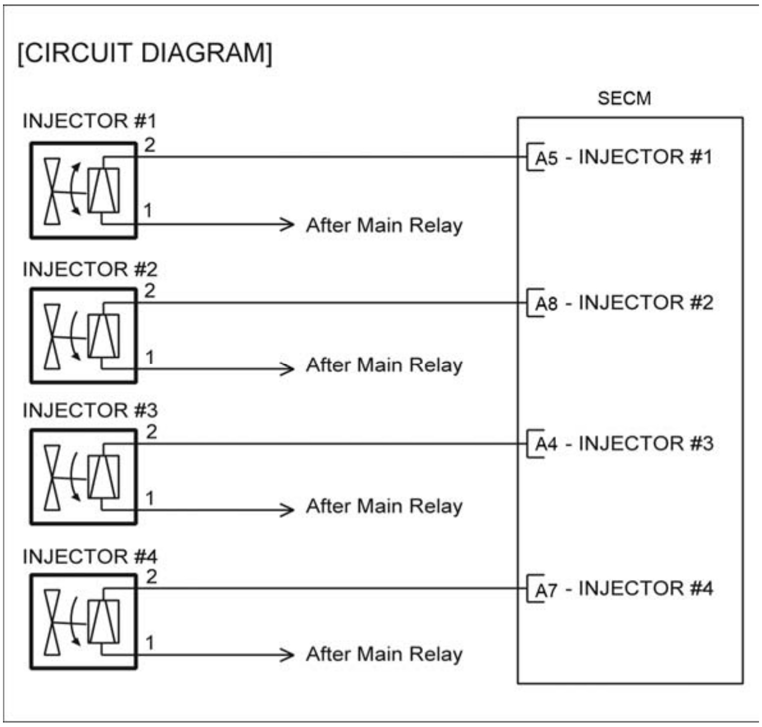
Description

Based on information from various sensors, the ECM measures the fuel injection amount. The fuel injector is a solenoid-operated valve and the fuel injection amount is controlled by length of time the fuel injector is held open. The ECM controls each injector by grounding the control circuit. When the ECM energizes the injector by grounding the control circuit, the circuit voltage should be low (theoretically 0V) and the fuel is injected. When the ECM de-energizes the injector by opening control circuit, the fuel injector is closed and circuit voltage should be peak for a moment.

Specification

Temperature		Injector Resistance(Ω)	Temperature		Injector Resistance(Ω)
(℃)	(°F)		(℃)	(°F)	
-20	-4	12.2 ~ 12.3	60	140	16.6 ~ 16.8
0	32	13.3 ~ 13.5	80	176	17.7 ~ 17.9
20	68	14.4 ~ 14.6	100	212	18.8 ~ 19.0
40	104	15.5 ~ 15.7	120	248	19.9 ~ 20.1

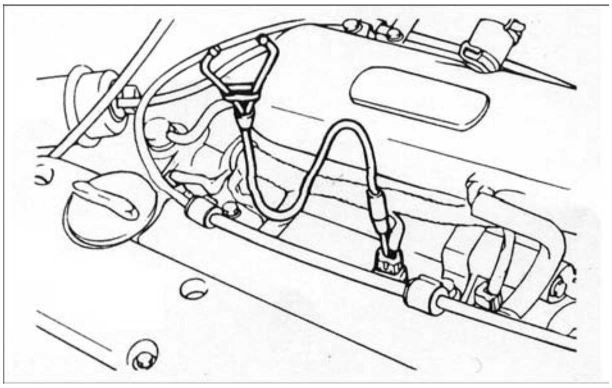
Schematic diagram



Injector Inspection

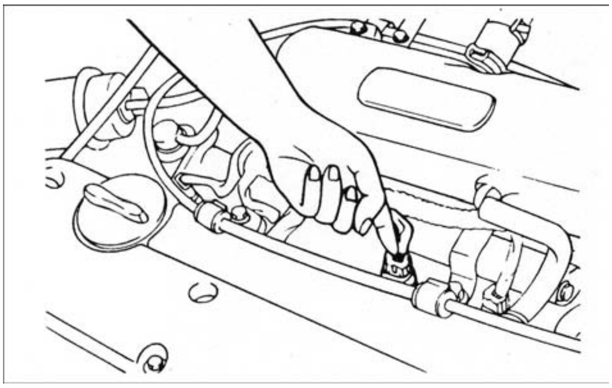
Operation check

Operation Sound Check



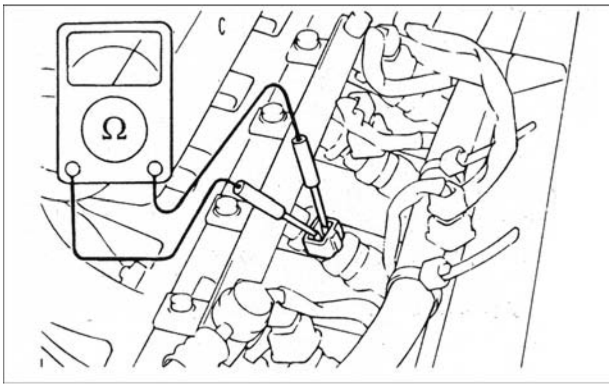
1. Using a stethoscope, check the injectors for a clicking sound at idle. Check that the sound is produced at shorter intervals as the engine speed increases.

NOTE: Ensure that the sound from an adjacent injector is not being transmitted along the delivery pipe to an inoperative injector.



2. If a stethoscope is not available, check the injector operation with your finger. If no vibrations are felt, check the wiring connector, injector, or injection signal from ECM.

Resistance Measurement Between Terminals



1. Disconnect the connector at the injector and measure the resistance between the two terminals.

Standard value : 14.5 ± 0.35Ω [at 20℃ (68°F)]

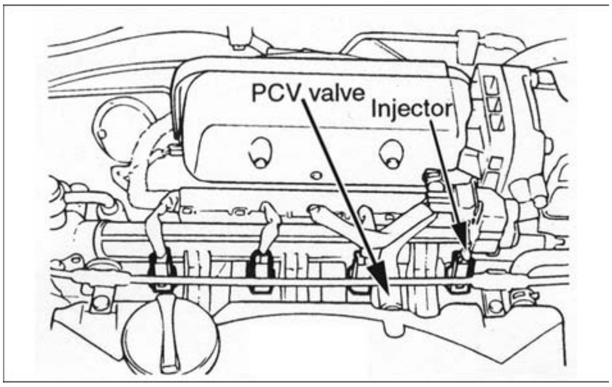
2. Re-connect the connector to the injector.

Removal

1. Release residual pressure from the fuel line to prevent fuel from spilling.

⚠ CAUTION

Cover the hose connection with rags to prevent splashing of fuel that could be caused by residual pressure in the fuel line.



2. Remove the delivery pipe with the fuel injectors.

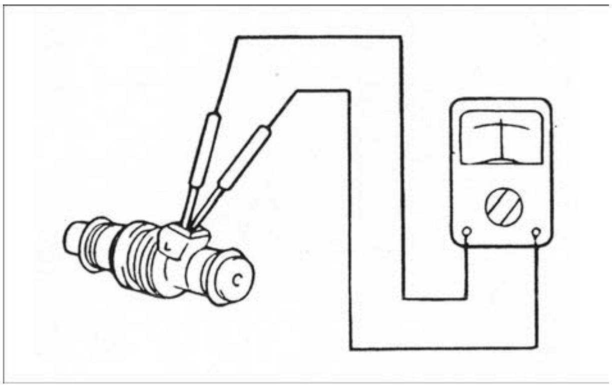
⚠ CAUTION

Be careful not to drop any injectors when removing the delivery pipe.
Be aware that fuel may flow out when removing the injector.

Inspection

1. Measure the resistance of the injectors between the terminals using an ohmmeter.

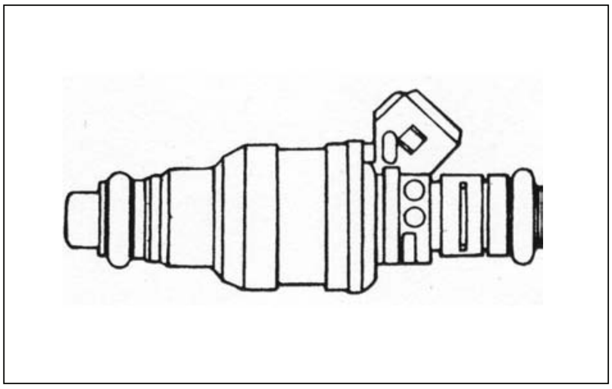
Resistance : 14.5 ± 0.35Ω [at 20℃ (68°F)]



2. If the resistance is not within specifications, replace the injector.

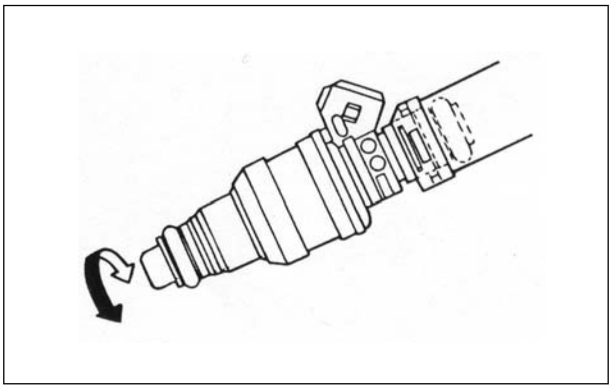
Installation

1. Install a new grommet and O-ring to the injector.



2. Apply a coating of solvent, spindle oil or gasoline to the O-ring of the injector.

3. While turning the injector to the left and right, fit it on to the delivery pipe.

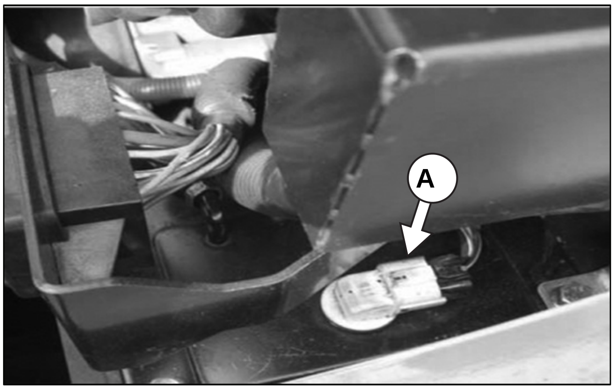


4. Be sure the injector turns smoothly.

NOTE: If it does turn smoothly, the O-ring may be jammed : Remove the injector and re-insert it into the delivery pipe and recheck.

Fuel Pump

Removal (Including Fuel Filter And Fuel Pressure Regulator)



1. Release the internal pressure of the fuel lines and hoses as following :

a. Disconnect the fuel pump assembly harness connector (A).

b. Start the engine and wait until fuel in fuel line is exhausted. After the engine stalls, turn the ignition switch to OFF position.

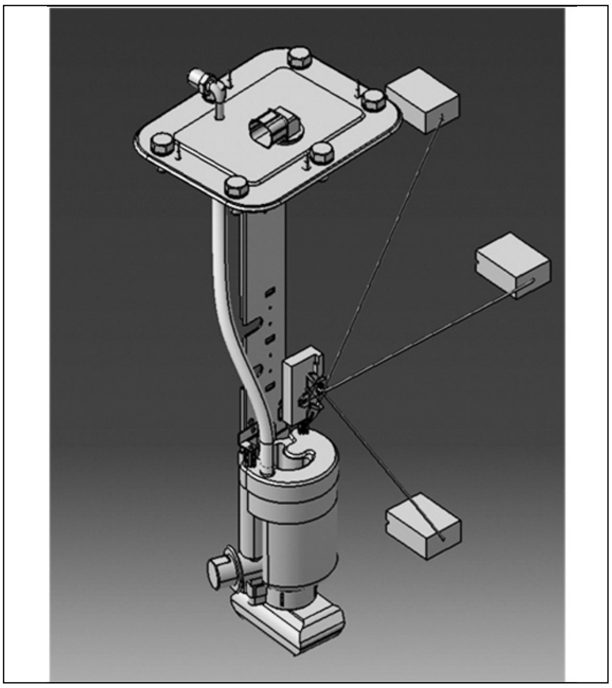
c. Disconnect the negative (-) terminal from the battery.

2. Disconnect the fuel feed line.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

3. Unfasten the fuel pump cap (D) counter clock wise.



4. Remove the fuel pump assembly.

Chapter 8. BASIC TROUBLESHOOTING

Preliminary Checks

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) and are covered in Chapter 9, Advanced Diagnostics. However, items such as fuel level, plugged fuel lines, clogged fuel filters, and malfunctioning pressure regulators may not set a fault code and usually can be corrected with the basic troubleshooting steps described on the following pages.

If engine or drivability problems are encountered with your MI-07 system, perform the checks in this section before referring to Advanced Diagnostics.

NOTE: Locating a problem in a propane engine is done exactly the same as with a gasoline engine. Consider all parts of the ignition and mechanical systems as well as the fuel system.

Before Starting

1. Determine that the SECM and MIL light are operating. Verify operation by keying on engine and checking for flash of MIL light. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

2. Determine that there are no diagnostic codes stored, or there is a diagnostic code but no MIL light.

Visual/Physical check

Several of the procedures call for a “Careful Visual/Physical Check” which should include:

- SECM grounds for being clean and tight
- Vacuum hoses for splits, kinks, and proper connection.
- Air leaks at throttle body mounting and intake manifold
- Exhaust system leaks
- Ignition wires for cracking, hardness, proper routing, and carbon tracking
- Wiring for pinches and cuts

Also check:

- Connections to determine that none are loose, cracked, or missing
- Fuel level in vehicle is sufficient
- Fuel is not leaking
- Battery voltage is greater than 11.5 volts
- Steering, brakes, and hydraulics are in proper condition and vehicle is safe to operate

NOTE: The Visual/Physical check is very important, as it can often correct a problem without further troubleshooting and save valuable time.

Basic Troubleshooting Guide

Customer Problem Analysis Sheet

1. Forklift Information

(I) VIN:
(II) ProductionDate:
(III) Hour meter Reading: (hrs)

2. Symptoms

☐ Unable to start	☐ Engine does not turn over ☐Incomplete combustion ☐ Initial combustion does not occur
☐ Difficult to start	☐ Engine turns over slowly ☐ Other_________________
☐ Poor idling	☐ Rough idling ☐ Incorrect idling ☐Unstable idling (High: ______ rpm, Low: ______ rpm) ☐ Other__________________________________
☐ Engine stall	☐ Soon after starting ☐ After accelerator pedal depressed ☐After accelerator pedal released ☐ Shifting from N to D-range ☐ Other____
☐ Others	☐ Poor driving (Surge) ☐ Knocking ☐ Poor fuel economy ☐ Back fire ☐ After fire ☐ Other____________________________

3. Environment

Problem frequency	☐ Constant ☐ Sometimes (_________________) ☐ Once only ☐ Other____
Weather	☐ Fine ☐ Cloudy ☐ Rainy ☐ Snowy ☐ Other__________________
Outdoor temperature	Approx._____ ℃/°F
Place	☐ Suburbs ☐ Inner City ☐ Uphill ☐ Downhill ☐ Rough road ☐ Other___________________________________
Engine temperature	☐ Cold ☐ Warming up ☐ After warming up ☐ Any temperature
Engine operation	☐ Starting ☐ Just after starting (____min) ☐ Idling ☐ Racing ☐ Driving ☐ Constant speed ☐ Acceleration ☐ Deceleration ☐ Other_____________________________

4. MIL/DTC

MIL (Malfunction Indicator Lamp)	☐ Remains ON ☐ Sometimes lights up ☐ Does not light
DTC	☐ Normal ☐ DTC(_______________________________________)

Basic Inspection Procedure

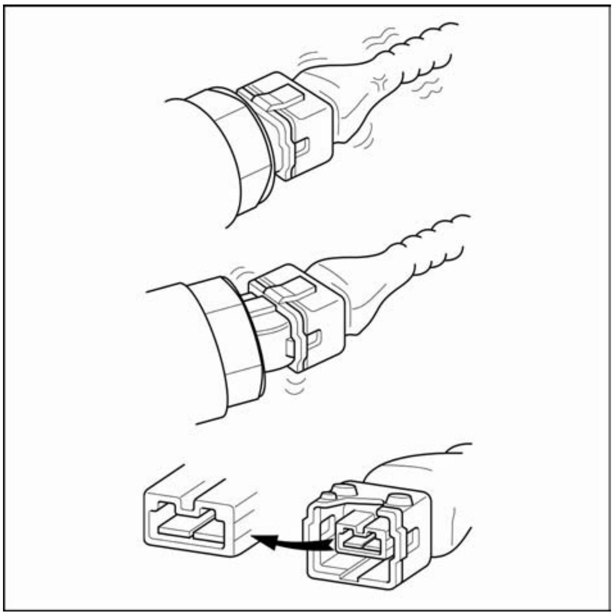
Measuring Condition Of Electronic Parts Resistance

The measured resistance at high temperature after vehicle running may be high or low. So all resistance must be measured at ambient temperature (20℃, 68 ℉), unless there is any notice.

NOTE: The measured resistance in except for ambient temperature (20℃, 68℉) is reference value.

Intermittent Problem Inspection Procedure

Sometimes the most difficult case in troubleshooting is when a problem symptom occurs but does not occur again during testing. An example would be if a problem appears only when the vehicle is cold but has not appeared when warm. In this case, technician should thoroughly make out a "CUSTOMER PROBLEM ANALYSIS SHEET" and recreate (simulate) the environment and condition which occurred when the vehicle was having the issue.



1. Clear Diagnostic Trouble Code (DTC).

2. Inspect connector connection, and check terminal for poor connections, loose wires, bent, broken or corroded pins, and then verify that the connectors are always securely fastened.

3. Slightly shake the connector and wiring harness vertically and horizontally.

4. Repair or replace the component that has a problem.

5. Verify that the problem has disappeared with the road test.

● SIMULATING VIBRATION

1) Sensors and Actuators
: Slightly vibrate sensors, actuators or relays with finger.

⚠ WARNING

Strong vibration may break sensors, actuators or relays.

2) Connectors and Harness
: Lightly shake the connector and wiring harness vertically and then horizontally.

● Simulating Heat

1) Heat components suspected of causing the malfunction with a hair dryer or other heat sourre.

⚠ WARNING

DO NOT heat components to the point where they may be damaged.
DO NOT heat the ECM directly.

● Simulating Water Sprinkling

1) Sprinkle water onto vehicle to simulate a rainy day or a high humidity condition.

⚠ WARNING

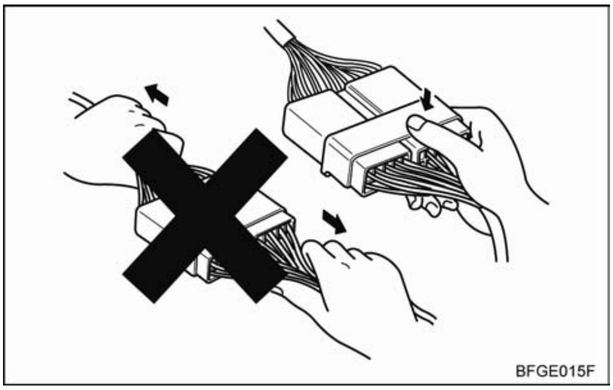
DO NOT sprinkle water directly into the engine compartment or electronic components.

● Simulatingelectricalload

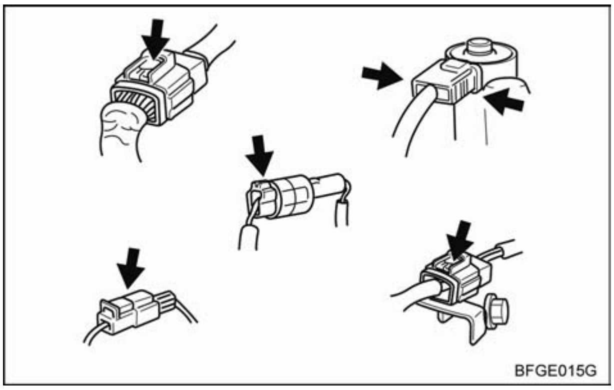
1) Turn on all electrical systems to simulate excessive electrical loads (Radios, fans, lights, etc.).

Connector Inspection Procedure

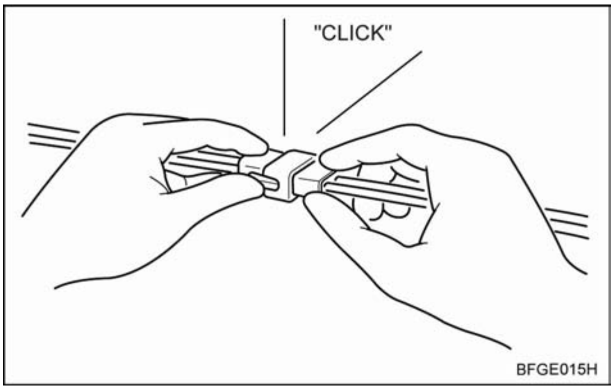
Handling of Connector



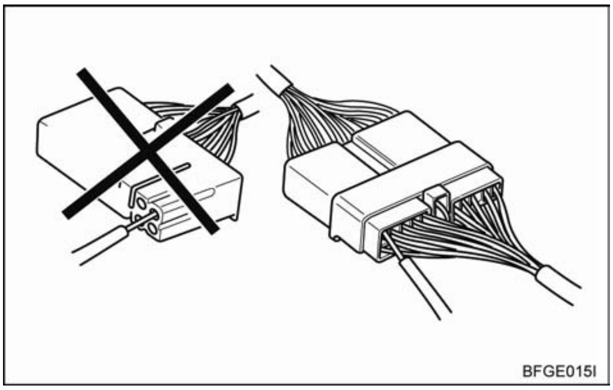
1. Never pull on the wiring harness when disconnecting connectors.



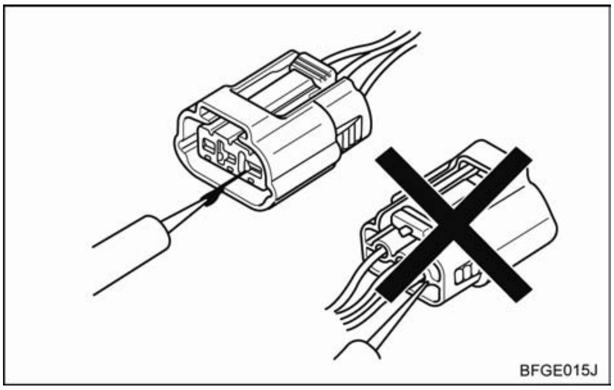
2. When removing the connector with a lock, press or pull locking lever.



3. Listen for a click when locking connectors. This sound indicates that they are securely locked.



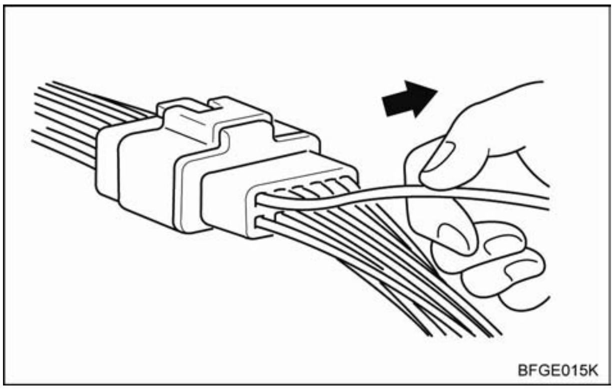
4. When a tester is used to check for continuity, or to measure voltage, always insert tester probe from wire harness side.



5. Check waterproof connector terminals from the connector side. Waterproof connectors cannot be accessed from harness side.

NOTE: Use a fine wire to prevent damage to the terminal. Do not damage the terminal when inserting the tater lead.

Checking Point for Connector



1. While the connector is connected:
Hold the connector, check connecting condition and locking efficiency.

2. When the connector is disconnected:
Check missed terminal, crimped terminal or broken core wire by slightly pulling the wire harness. Visually check for rust, contamination, deformation and bend.

3. Check terminal tightening condition:
Insert a spare male terminal into a female terminal and then check terminal tightening conditions.

4. Pull lightly on individual wires to ensure that each wire is secured in the terminal.

Repair Method of Connector Terminal

1. Clean the contact points using air gun and/or shop rag.

NOTE: Never uses and paper when polishing the contact points, otherwise the contact point may be damaged.

2. In case of abnormal contact pressure, replace the female terminal.

Wire Harness Inspection Procedure

1. Before removing the wire harness, check the wire harness position and crimping in order to restore it correctly.

2. Check whether the wire harness is twisted, pulled or loosened.

3. Check whether the temperature of the wire harness is abnormally high.

4. Check whether the wire harness is rotating, moving or vibrating against the sharp edge of a part.

5. Check the connection between the wire harness and any installed part.

6. If the covering of wire harness is damaged; secure, repair or replace the harness.

Electrical Circuit Inspection Procedure

● Check Open Circuit

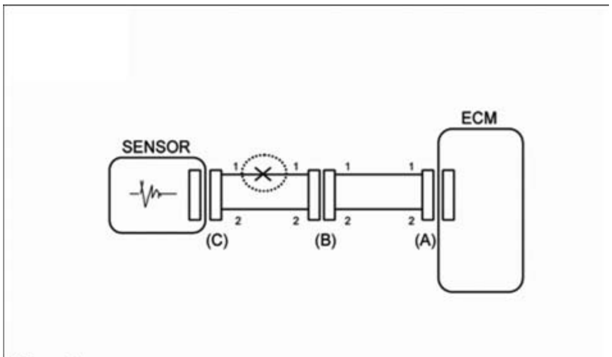


Figure 1 BFGE501A

1. Procedures for Open Circuit

- Continuity Check
- Voltage Check

If an open circuit occurs (as seen in [FIG.1]), it can be found by performing Step 2 (Continuity Check) or Step 3 (Voltage Check Method) as shown below.

2. Continuity Check Method

NOTE: When measuring for resistance, lightly shake the wire harness above and below or from side to side.

Specification (Resistance)
1Ω or less → Normal Circuit
1MΩ or Higher → Open Circuit

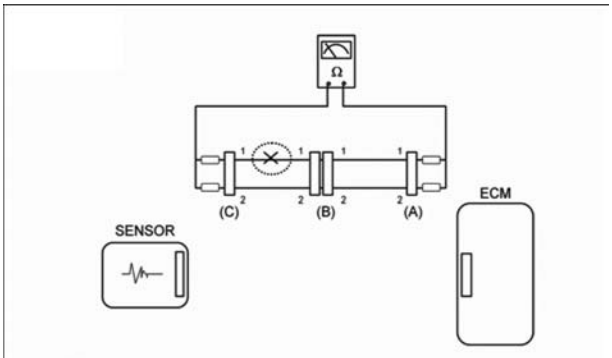


Figure 2 BFGE501B

a. Disconnect connectors (A), (C) and measure resistance between connector (A) and (C) as shown in [FIG.2].

In [FIG.2.] the measured resistance of line1and 2 is higher than 1MΩ and below 1Ω respectively. Specifically the open circuit is line 1(Line 2 is normal). To find exact break point, check sub line of line 1as described in next step.

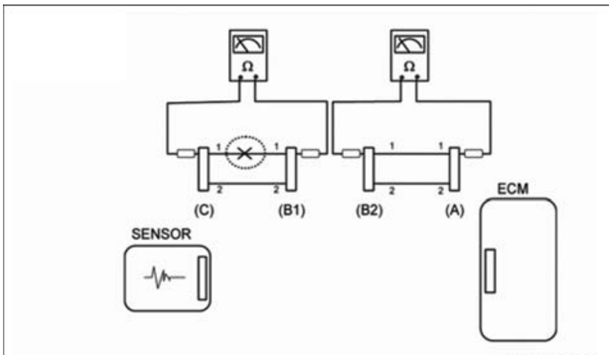


Figure 3 BFGE501C

b. Disconnect connector (B), and measure for resis tance between connector (C) and (B1) and between (B2) and (A) as shown in [FIG.3]. In this case the measured resistance between connector (C) and (B1) is higher than 1MΩ and the open circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

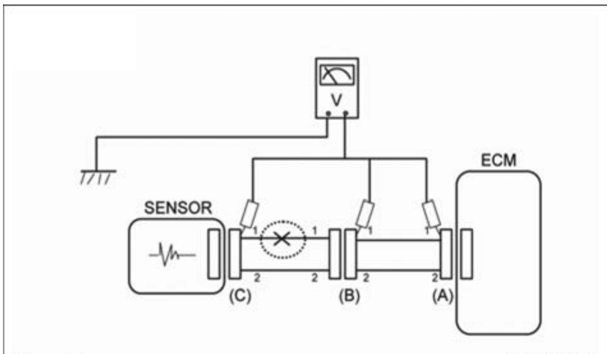


Figure 3 BFGE501D

3. Voltage Check Method

a. With each connector still connected, measure the voltage between the chassis ground and terminal1 of each connectors (A), (B) and (C) as shown in [FIG.4].

The measured voltage of each connector is 5V, 5V and 0V respectively. So the open circuit is between connector (C) and (B).

● Check Short Circuit

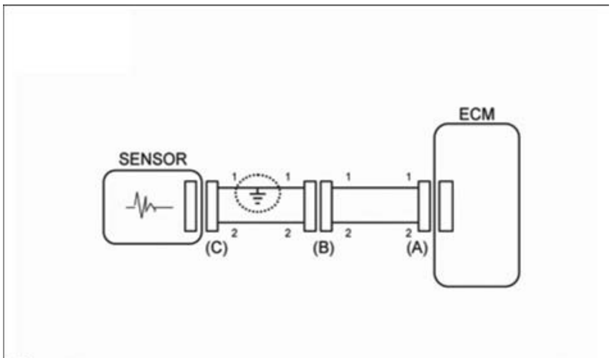


Figure 5 BFGE501E

1. Test Method for Short to Ground Circuit

• Continuity Check with Chassis Ground

If short to ground circuit occurs as shown in [FIG.5], the broken point can be found by performing below Step 2 (Continuity Check Method with Chassis Ground) as shown below.

2. Continuity Check Method (with Chassis Ground)

NOTE: Lightly shake the wire harness above and below, or from side to side when measuring the resistance.

Specification (Resistance)
1Ω or less → Short to Ground Circuit
1MΩ or Higher → Normal Circuit

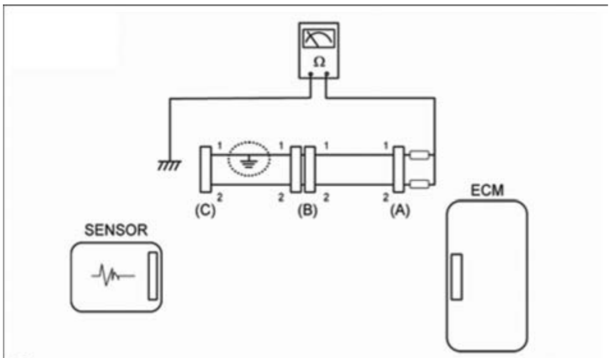


Figure 6 BFGE501F

a. Disconnect connectors (A), (C) and measure for resistance between connector (A) and Chassis Ground as shown in [FIG.6].

The measured resistance of line 1 and 2 in this example is below 1Ω and higher than 1MΩ respectively. Specifically the short to ground circuit is line 1 (Line 2is normal). To find exact broken point, check the sub line of line1 as described in the following step.

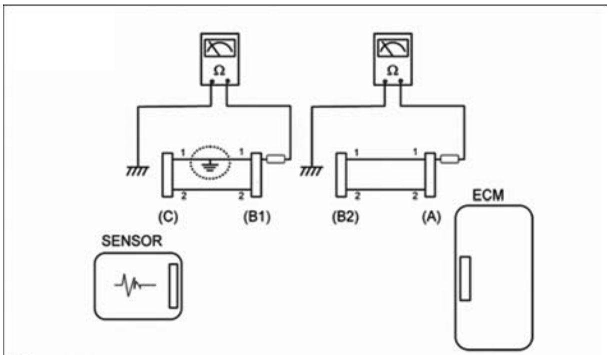


Figure 7 BFGE501G

b. Disconnect connector (B), and measure the resistance between connector (A) and chassis ground, and between (B1) and chassis ground as shown in [FIG.7].

The measured resistance between connector (B1) and chassis groundis1Ω or less. The short to ground circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

Symptom Troubleshooting Guide Chart for MPI Gasoline Engine

Engine Is Not Starting

Power check →

- o Battery
  1. Connection
  2. Specific gravity
  3. Driving belt
  4. Voltage
- o Fusible link

↓ OK

Starting system check →

- o Ignition switch
- o Starting relay
- o Starting motor
- o Wiring

Engine Is Difficult To Start(Cranking OK)

Self- diagnosis inspection → Fault code →

Fault code
- o Use Hi-scan
- o L-wire using engine
  Warning display number reading

↓ Normal code

Vacuum leak check →

- o Oil filler cap
- o Oil dipstick
- o Vacuum hose connection
- o PCV hose

↓ OK

Spark plug inspection
- o Disconnect injector connector
- o With spark plug removed 8-10mm away from cylinder block, crank and inspect strong spark

→

- o High tension cable
- o Ignition coil, Spark plug

↓ OK

Continued

Fuel supply to injector check
- o Fuel in tank
- o Fuel pressure

→
- o Fuel line (Leak, Deformation)
- o Fuel pump
- o Fuel filter
- o Fuel pressure regulator
- o Regulator (-) pressure check

↓ OK

Ignition plug inspection
Standard: 0.7-0.8mm
- o Inspect compression if necessary

↓ OK

Ignition timing inspection

↓ OK

MPI electronic circuit inspection

→
- o Wiring connection
- o ECU power
  1. Fusible link
  2. Fuse
  3. MPI main relay
- o Engine cooling temperature sensor
- o Intake temperature sensor
- o Injection signal circuit
  1. Injector wiring
  2. ECU
- o Throttle position sensor (TPS)
- o MAP sensor
- o Crankshaft position sensor

Irregular Idling Or Engine Is Suddenly Stopped

Self- diagnosis inspection

→ Fault code
- o Use Hi-scan

Warning display number reading

↓ OK

Vacuum leak check

→
- o Oil filler cap
- o Oil dipstick
- o Vacuum hose connection
- o PCV hose

↓ OK

Fuel supply to injector check
- o Fuel in tank
- o Fuel pressure

→
- o Fuel line (Leak, Deformation)
- o Fuel pump
- o Fuel filter
- o Fuel pressure regulator

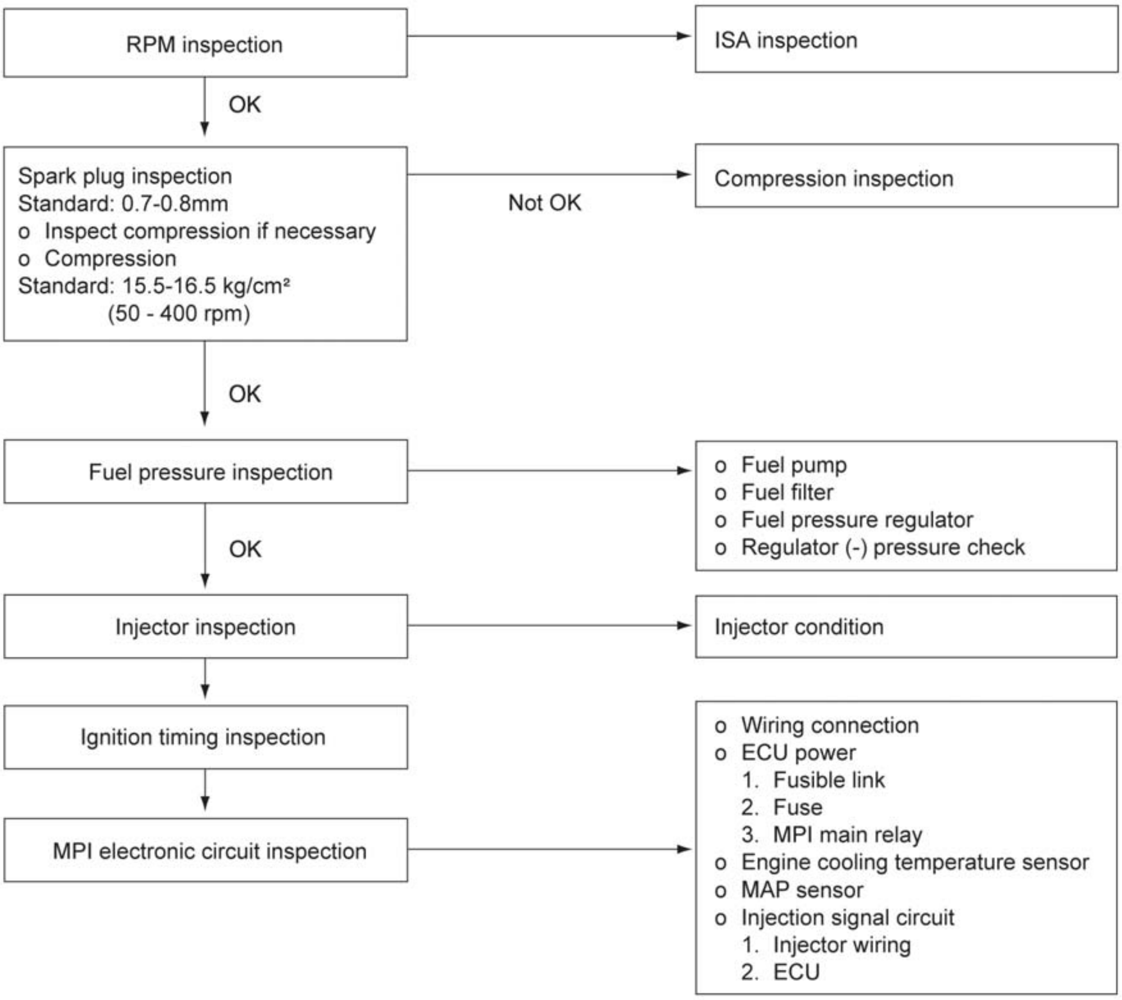
↓ OK

Air cleaner element inspection

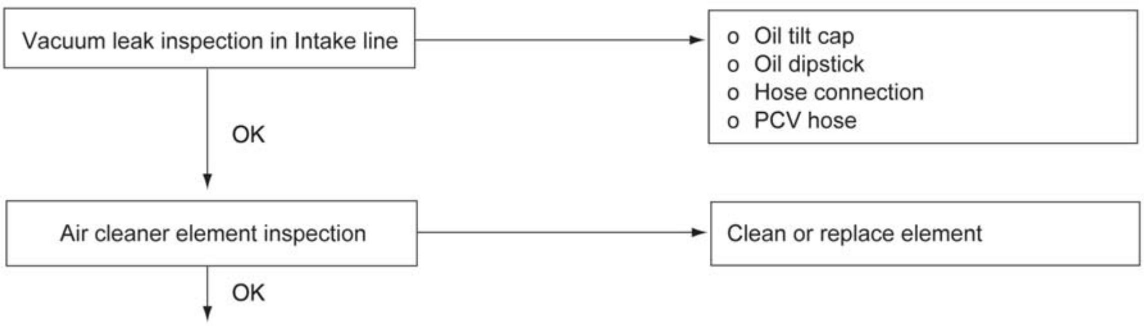
→ Clean or replace element

↓ OK

Continued



Engine Hesitation Or Insuffient Accelelation



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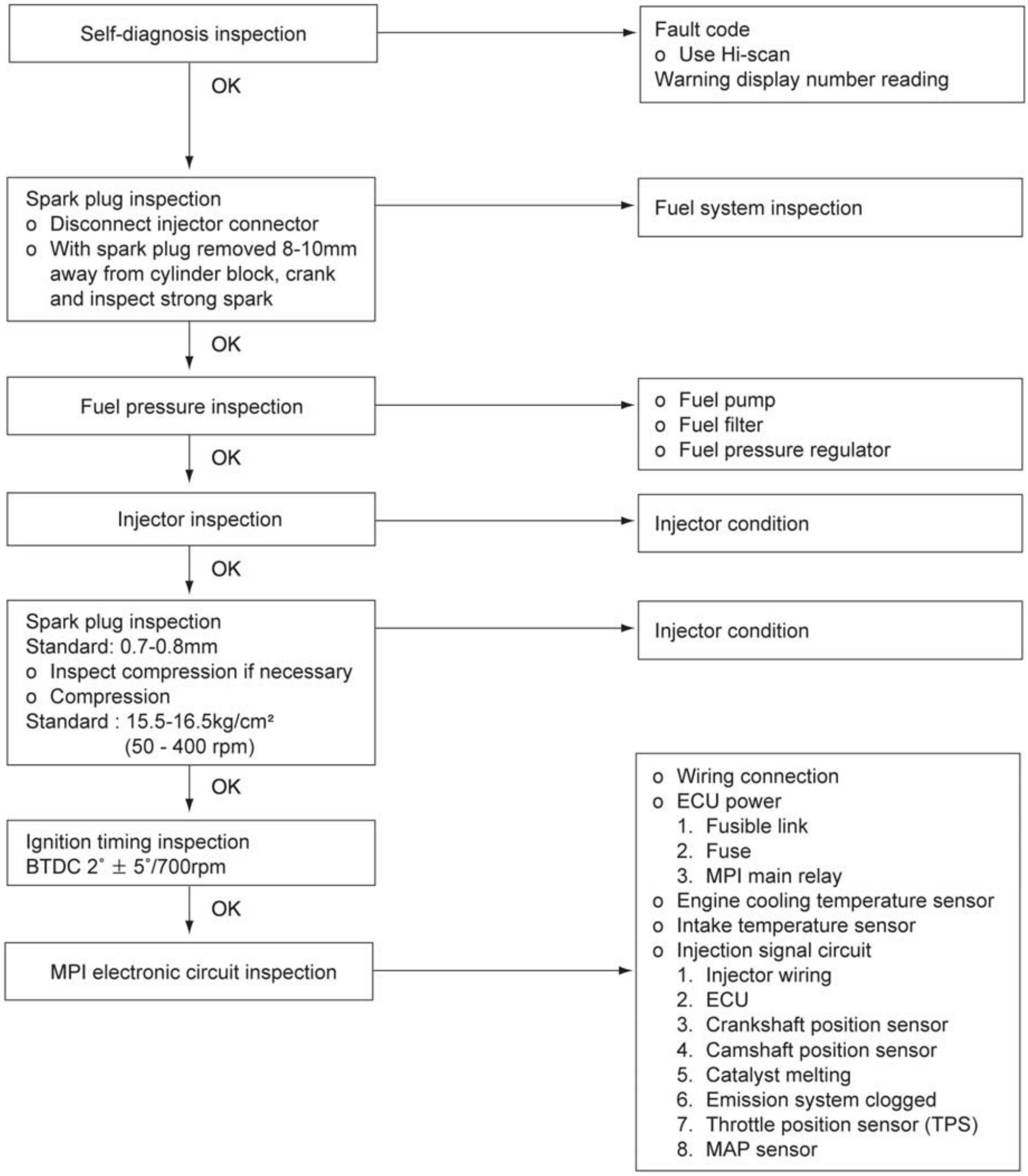

Self-diagnosis inspection
Fault code
o Use Hi-scan
Warning display number reading
OK
Spark plug inspection
o Disconnect injector connector
o With spark plug removed 8-10mm away from cylinder block, crank and inspect strong spark
Fuel system inspection
OK
Fuel pressure inspection
o Fuel pump
o Fuel filter
o Fuel pressure regulator
OK
Injector inspection
Injector condition
OK
Spark plug inspection
Standard: 0.7-0.8mm
o Inspect compression if necessary
o Compression
Standard : 15.5-16.5kg/cm²
(50 - 400 rpm)
Injector condition
OK
Ignition timing inspection
BTDC 2˚ ± 5˚/700rpm
OK
MPI electronic circuit inspection
o Wiring connection
o ECU power
1. Fusible link
2. Fuse
3. MPI main relay
o Engine cooling temperature sensor
o Intake temperature sensor
o Injection signal circuit
1. Injector wiring
2. ECU
3. Crankshaft position sensor
4. Camshaft position sensor
5. Catalyst melting
6. Emission system clogged
7. Throttle position sensor (TPS)
8. MAP sensor

Troubleshooting Guide for MPI Gasoline Engine

• The following number represents inspection order.

Main symptom	Sub symptom \ Item	Starter relay	Starter	Flywheel	Airflow sensor circuit	Fuel pressure regulator	Water temperature sensor	Compression	Piston ring	Ignition timing	Timing belt	Injector	ECU	A/C circuit	Connecting rod bearing	Fuel chamber	Crankshaft bearing
Starting	Not cranking	1	2														
	Starter is rotating but not cranking		1	2													
	Incomplete combustion				1	2	3	4	5	6	7	8	9				
	Increasingly cranking		1											2	3	4	
	Normally difficult to start					4	3	7	8	9		12	13				1
	Difficult to start when cold					4	1					7	8				2
	Difficult to start when hot					4	1					7	8				2
Faulty idling	Incorrect initial idling						1					4	5	3			
	Low RPM				2		1					3	4				
	Irregular idling				9	4		7	8	10	11	12	14				1
	Engine hesitation or deceleration				4	8	5	3		11		12	13				1
Engine stops	After starting, engine stops soon				5	2	6					7	8				1
	After depressing acceleration pedal, engine stops				1	3						5	6				
	After releasing acceleration pedal, engine stops				1								2				
	With A/C ON, engine stops												2	1			
Other	Fuel over-consumption				11		10	6	7	8		9	14	12		1	5

Main symptom	Item / Sub symptom	Crankshaft position sensor	Spark plug	Fuel pump	Fuel line	Ignition circuit	Intake temperature sensor circuit	Cylinder head	Oxygen sensor circuit	Fuel leak
Starting	Not cranking									
	Starter is rotating but not cranking	3								
	Incomplete combustion									
	Increasingly cranking									
	Normally difficult to start		2	5	6	10	11			
	Difficult to start when cold			5	6		3			
	Difficult to start when hot			5	6		3			
Faulty idling	Incorrect initial idling						2			
	Low RPM									
	Irregular idling		3	5	6	13	2	15		
	Engine hesitation or deceleration		2	9	10		6		7	
Engine stops	After starting, engine stops soon			3	4					
	After depressing acceleration pedal, engine stops		2		4					
	After releasing acceleration pedal, engine stops									
	With A/C ON, engine stops									
Other	Fuel over-consumption		4			13	2	3		

Main symptom	Item / Sub symptom	Coolant leak	Cooling pan	Cooling pan switch	Radiator and radiator cap	Thermostat	Timing belt	Water pump	Spark plug	Oil pump	Cylinder head	Cylinder block	Coolant temperature gauge
Other	Engine is overheated	1	2	3	4	5	6	7	8	9	10	11	12
	Engine is supercooled		1			2							3

Basic Troubleshooting

Intermittents

An intermittent fault is the most difficult to troubleshoot since the MIL flashes on at random, causing uncertainty in the number of flashes or the conditions present at the time of the fault. Also, the problem may or may not fully turn “ON” the MIL light or store a code.

Therefore, the fault must be present or able to be recreated in order to locate the problem. If a fault is intermittent, use of diagnostic code charts may result in the unnecessary replacement of good components.

Corrective Action

Most intermittent problems are caused by faulty electrical connections or wiring. Perform careful visual/physical check for:

- Poor mating of the connector halves or terminal not fully seated in the connector body (backed out)
- Improperly formed or damaged terminal. All connector terminals in problem circuit should be carefully reformed or replaced to insure proper contact tension
- Loose connections or broken wires
- Poor terminal to wire connection crimp

If a visual/physical check does not find the cause of the problem, perform the following:

(1) Drive the vehicle with a voltmeter or “Service” tool connected to a suspected circuit. Check if circuit is active and signal is reasonable.

(2) Using the “Service” tool, monitor the input signal to the SECM to help detect intermittent conditions.

(3) An abnormal voltage, or “Service” reading, when the problem occurs, indicates the problem may be in that circuit.

(4) If the wiring and connectors check OK, and a diagnostic code was stored for a circuit having a sensor, check sensor.

An intermittent “Service Engine Soon” light with no stored diagnostic code may be caused by:

- Ignition coil shortage to ground and arcing at spark plug wires or plugs
- MIL light wire to ECM shorted to ground
- SECM grounds (refer to SECM wiring diagrams).

Check for improper installation of electrical options such as lights, 2-way radios, accessories, etc.

EST wires should be routed away from spark plug wires, distributor wires, distributor housing, coil and generator. Wires from SECM to ignition should have a good connection.

Surges and/or Stumbles

Engine power varies under steady throttle or cruise. Feels like the vehicle speeds up and slows down with no change in the acceleration pedal.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver understands vehicle operation as explained in the operator manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Oxygen sensor malfunction	The fuel management should maintain a stoichiometric air-fuel ratio under all steady state operating conditions following engine warmup. Failure of the Pre-catalyst O2 sensor should cause an O2 sensor fault that can be diagnosed with the MIL lamp or Service Tool.
Fuel system malfunction	NOTE: To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring pre-catalyst O2 adapts*, dither valve duty cycle, or mechanical injector pulse width will help identify problem. Check fuel supply while condition exists. Check in-line fuel filter. Replace if dirty or plugged. Check fuel pressure.
Ignition system malfunction	Check for proper ignition voltage output using spark tester. Check spark plugs. • Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. • Repair or replace as necessary. • Check condition of distributor cap, rotor and spark plug wires (where applicable). Check ignition timing. Refer to application manual for specs.
Component malfunction	Check vacuum lines for kinks or leaks. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Exhaust backpressure	Check condition of exhaust system. Check backpressure before catalyst. It should be less than 3.5 psig (24.13 kPa).

(*) Refer to Table 1 for description of gaseous and liquid O2 adapts.

Related MIL Faults:
Pre-catalyst O2 sensor errors / O2 control errors
Dither valve DC faults / EST faults / ETC faults

Engine Cranking but Will Not Start / Difficult to Start

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver is using correct method to start engine as explained in operator's manual. Use "clear flood" mode during cranking by fully depressing the pedal and cranking the engine. If engine does not start, continue troubleshooting.

PROBABLE CAUSE	CORRECTIVE ACTION
CORRECTIVE ACTION	Verify "selected" fuel with Service Tool. Make sure fuel select switch is in proper position.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Liquid valve closed	Slowly open liquid valve.
Propane excess flow valve closed	Reset excess flow valve in LPG tank. Close liquid valve. Wait for a "click" sound; slowly open liquid valve.
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve. • Leak test.
Clogged fuel filter	Repair/replace as required. See Chapter 2 Fuel Filter replacement.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 2 Fuel Lock-off.
Pressure regulator/converter malfunction	Test regulator/converter operation and pressure. See Chapter 6 Tests and Adjustments.
Incorrect air/fuel or ignition/spark control	See Chapter 8 Advanced Diagnostics.
No crankshaft position sensor signal	Verify the crankshaft position signal is present See Chapter 8 Advanced Diagnostics.

Engine Cranking but Will Not Start / Difficult to Start (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
SECM / control system malfunction	Check Coolant Temperature Sensor using the Service Tool; compare coolant temperature with ambient temperature on cold engine. If coolant temperature reading is 5° greater than or less than ambient air temperature on a cold engine, check resistance in coolant sensor circuit or sensor itself. Compare CTS resistance value to "Diagnostic Aids" chart at end of this section. Verify that there is no code for ETC spring check fault. Check for 0% APP during cranking. Cycle key ON and OFF and listen for throttle check (movement) on key OFF. Check for oil pressure switch faults. Check for sensor "sticking" faults. Check TPS for stuck binding or a high TPS voltage with the throttle closed.
Fuel system malfunction	Check fuel lock off (propane) or fuel pump relay gasoline operation: actuator should turn "ON" for 2 seconds when ignition is turned "ON". Check fuel pressure. Check for contaminated fuel. Check both gasoline injector and lock off fuses (visually inspect). Check propane tank valve & pickup. A faulty in-tank fuel pump check valve will allow the fuel in the lines to drain back to the tank after engine is stopped. To check for this condition, perform fuel system diagnosis. Check FTV system for proper operation.
Ignition system malfunction	Check for proper ignition voltage output with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check for: • Moisture in distributor cap* • Bare or shorted wires • Worn distributor shaft/rotor* • Loose ignition coil ground • Pickup coil resistance and connections* (*) Where present

Related MIL Faults:
ETC spring check / ETC faults / EST faults / TPS conflict
APP faults / Encoder error / MAP faults
Injector faults / Oil pressure faults

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration

Engine delivers less than expected power. Little or no increase in speed when accelerator pedal is pushed down part way. Momentary lack of response as the accelerator is pushed down. Can occur at all vehicle speeds. Usually most severe when first trying to make vehicle move, as from a stop. May cause engine to stall.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Drive vehicle; verify problem exists. Remove air filter and check for dirt or other means of plugging. Replace if needed.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for restricted fuel filter. Check fuel supply. Check for LPG vapor from LPG liquid outlet valve on tank. Check for contaminated fuel. Check for clogged fuel filter and repair or replace as required. See Chapter 4 Fuel Filter replacement Check for plugged fuel line and remove any obstruction from the fuel line: • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve and leak test. Check for faulty vapor connection between pressure regulator/converter and mixer: • Verify that there are no holes in hose. • Observe that clamps are tight. • Look for kinked, pinched and/or collapsed hose. Monitor pre-catalyst O2 with Service Tool. Check for proper pressure regulator operation. See Chapter 6 Test and Adjustments. Check for proper air/fuel mixer operation.
Ignition system malfunction	Check spark advance for excessive retarded ignition timing. Use Service Tool. Check secondary voltage using an oscilloscope or a spark tester to check for a weak coil. Check spark plug condition. Check poor spark plug primary and secondary wire condition.

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Component malfunction	Check SECM grounds for cleanliness and secure connection. See SECM wiring diagrams. Check alternator output voltage. Repair if less than 9 volts or more than 16 volts. Check for clogged air filter and clean or replace as required. Check exhaust system for possible restriction. Refer to Chart T-1 on later pages. Inspect exhaust system for damaged or collapsed pipes. • Inspect muffler for heat distress or possible internal failure. • Check for possible plugged catalytic converter by comparing exhaust system backpressure on each side at engine. Check backpressure by removing Pre-catalyst O2 sensor and measuring backpressure with a gauge.
Engine mechanical	See Chapter 3 Engine Mechanical System. Check engine valve timing and compression Check engine for correct or worn camshaft.

Related MIL Faults:
EST faults
ETC faults
ETC spring check
TPS faults
APP faults
Encoder error
Delayed Shutdown faults

Detonation / Spark Knock

A mild to severe ping, usually worse under acceleration. The engine makes sharp metallic knocks that change with throttle opening (similar to the sound of hail striking a metal roof).

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for proper fuel level: • Check for LPG vapor from LPG liquid outlet valve on tank. • Fill fuel container. Do not exceed 80% of liquid capacity. Check fuel pressure. To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring with the Service tool will help identify problem.
Cooling system malfunction	Check for obvious overheating problems: • Low engine coolant • Loose water pump belt • Restricted air flow to radiator, or restricted water flow through radiator • Inoperative electric cooling fan • Correct coolant solution should be a mix of anti-freeze coolant (or equivalent) and water • High coolant temperature
Ignition system malfunction	Check ignition timing. See application manual. Check spark module wiring.
Exhaust system malfunction	Check exhaust backpressure. Check for debris clogging the catalyst. Check that pre-catalyst O2 sensor is functioning.
Engine mechanical	Check for excessive oil in the combustion chamber and/or blow by from excessive PCV flow. Check combustion chambers for excessive carbon build up. Check combustion chamber pressure by performing a compression test. Check for incorrect basic engine parts such as cam, heads, pistons, etc.

Related MIL Faults:
EST faults
Encoder error
High coolant temperature faults

Backfire

Fuel ignites in intake manifold or in exhaust system, making loud popping noise.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Simulate condition by reviewing operation procedure practiced by vehicle operator.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Perform fuel system diagnosis check: • Check for fuel leaks • Check for MIL faults • Check for damaged components
Ignition system malfunction	Check proper ignition coil output voltage with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check spark plug wires for crossfire; also inspect distributor cap, spark plug wires, and proper routing of plug wires. Check ignition timing. Refer to application manual.
Engine mechanical	Check compression: look for sticking or leaking valves. Check intake and exhaust manifold for casting flash and gasket misalignment. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults: EST faults / ETC faults / Encoder error
Pre-catalyst O2 sensor faults

Dieseling, Run-on

Engine continues to run after key is turned "OFF," but runs very roughly. If engine runs smoothly, check ignition switch and adjustment.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for fuel leaks or leaking injector.
Ignition switching	Make sure power to system is shut off when key is in OFF position.
Fuel lock off valve	Make sure lock off valve is closing properly.
Ignition system malfunction	Check spark advance at idle.

Related MIL Faults: EST faults / ETC faults / Pre-catalyst O2 sensor faults

Rough, Unstable, Incorrect Idle, or Stalling

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of “Basic Troubleshooting” chapter. Check for vacuum leaks. Check that SECM grounds are clean and tight. See SECM wiring diagram

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Monitor oxygen feedback to help identify the cause of the problem. If the system is running lean or if the system is running rich evaluate further i.e. dither valve duty cycle and injector pulse width. Check for incorrect minimum idle speed that may be caused by foreign material accumulation in the throttle bore, on the throttle valve, or on the throttle shaft. Check that the injectors are clean and functioning. Check for liquid fuel in propane pressure regulator hose. If fuel is present, replace regulator assembly. The pre-catalyst oxygen (O2) sensor should respond quickly to different throttle positions. If it does not, then check the pre-catalyst O2 sensor for contamination. If the pre-catalyst O2 sensor is aged or contaminated, the SECM will not deliver correct amount of fuel, resulting in a drivability problem.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Ignition system malfunction	Check ignition system; wires, plugs, rotor, etc.
LPG pressure regulator malfunction	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments
Air/fuel mixer malfunction	Check mixer.
Component malfunction	Check throttle for sticking or binding. Check PCV valve for proper operation by placing finger over inlet hole in valve end several times. Valve should snap back. If not, replace valve. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Engine mechanical	Perform a cylinder compression check. See Chapter 3 Engine Mechanical System.

Rough, Unstable, Incorrect Idle, or Stalling (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Excess flow valve closed	Reset excess flow valve. • Close liquid valve. • Wait for a "click" sound. Slowly open liquid valve.
Clogged fuel filter	Repair/replace as required See Chapter 4 Fuel Filter Replacement
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve & leak test.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 4 Fuel Lock-Off.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection. • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Pressure regulator freezes	Check level in cooling system: • Must be full, check coolant strength • -35°F (-37°C) minimum Check coolant hoses. • Watch for kinks and/or pinched hoses. • Verify one pressure hose and one return hose. Test regulator. See Chapter 6
Vacuum leak	Check for vacuum leaks. • Between mixer and throttle body • Between throttle body and intake manifold • Between intake manifold and cylinder head

Related MIL Faults:
EST faults
ETC Sticking fault
Pre-catalyst adapts error

Cuts Out, Misses

Steady pulsation or jerking that follows engine speed, usually more pronounced as engine load increases, sometimes above 1500 rpm. The exhaust has a steady spitting sound at idle or low speed.

PRELIMINARY CHECKS
Perform the visual checks as described at start of “ Basic Troubleshooting” chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check fuel system specifically for plugged fuel filter, low pressure. Check for contaminated fuel. Check injector drivers. Disconnect all injector harness connectors. Use injector test light or equivalent 6-volt test light between the harness terminals of each connector and observe if light blinks while cranking. If test light fails to blink at any connector, it is a faulty injector drive circuit harness, connector, or terminal. Check lock off intermittent connection. Check dither valve operation.
Ignition system malfunction	Check for spark on the suspected cylinder(s) using a shop oscilloscope or spark tester or equivalent. If no spark, check for intermittent operation or miss. If there is a spark, remove spark plug(s) in these cylinders and check for cracks, wear, improper gap, burned electrodes, heavy deposits. Check spark plug wires by connecting ohmmeter to ends of each wire in question. If meter reads over 30,000 ohms, replace wire(s). Visually inspect distributor cap, rotor, and wires for moisture, dust, cracks, burns, etc. Spray cap and plug wires with fine water mist to check for shorts. Check engine ground wire for looseness or corrosion.
Component malfunction	Check for electromagnetic interference (EMI). A missing condition can be caused by EMI on the reference circuit. EMI can usually be detected by monitoring engine rpm with Service Tool. A sudden increase in rpm with little change in actual engine rpm indicates EMI is present. If problem exists, check routing of secondary wires and check distributor ground circuit. Check intake and exhaust manifolds for casting flash or gasket leaks.
Engine mechanical	Perform compression check on questionable cylinders. If compression is low, repair as necessary. Check base engine. Remove rocker covers and check for bent pushrods, worn rocker arms, broken valve springs, worn camshaft lobes, and valve timing. Repair as necessary.

Related MIL Faults:
EST faults
ETC Sticking fault

Poor Fuel Economy / Excessive Fuel Consumption LPG Exhaust Smell

Fuel economy, as measured during normal operation, is noticeably lower than expected. Also, economy is noticeably lower than what it has been in the past. Propane fuel smell near vehicle sets off carbon monoxide sensors.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Verify operator complaint: identify operating conditions. Check operator's driving habits: Are tires at correct pressure? Are excessively heavy loads being carried? Is acceleration too much, too often? Check air cleaner element (filter) for being dirty or plugged. Visually (physically) check vacuum hoses for splits, kinks, and proper connections as shown on application manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for faulty gasoline pressure regulator. Check for leaking injector. Check that dither valve duty cycle is < 15%. Check for too high propane pressure at mixer (> 1" positive pressure). Monitor Pre-catalyst O2 sensor with Service Tool.
Cooling system malfunction	Check engine coolant level. Check engine thermostat for faulty part (always open) or for wrong heat range.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check for weak ignition and/or spark control. Check spark plugs. Remove spark plugs and check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary.
Component malfunction	Check for exhaust system restriction or leaks. Check induction system and crankcase for air leaks. Check for clogged air filter; clean or replace as required. Check FTV for housing cracks or obstructions; repair or replace as required. Check for vacuum leak. Check system vacuum hoses from regulator to FTV and mixer. Repair or replace as required.
Air/fuel mixer malfunction	Check mixer.
Pressure regulator malfunction / fuel pressure too high	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments.
Engine mechanical	Check compression. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults:
Pre-catalyst O2 sensor faults / Low side driver / Dither valve duty cycle
EST faults / Fuel adapt faults / Low coolant temperature

High Idle Speed

Engine idles above the range of 700-1000 rpm.

PRELIMINARY CHECKS
Perform the visual checks as described at start of “ Basic Troubleshooting” chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Incorrect idle speed control	Check all hoses and gaskets for cracking, kinks, or leaks. Verify that there are no vacuum leaks. See Chapter 8 Advanced Diagnostics & Chapter 6 Tests and Adjustments
Throttle sticking	Replace throttle. See Fault Code 461: ETC_Sticking
Foot pedal sticking or incorrect pedal signal	Check pedal return spring travel for binding. Check APP function with Service Tool. Verify smooth change of APP reading with pedal movement. See Chapter 8 Advanced Diagnostics.
Engine mechanical	Check for vacuum hose leak. Check for PCV malfunction. Check for defective intake gasket.

Related MIL Faults:
ETC Sticking fault
Idle adapt out of range
MAP Sticking fault
MAP high value

Excessive Exhaust Emissions or Odors

Vehicle has high CO emissions.
NOTE: Excessive odors do not necessarily indicate excessive emissions.

PRELIMINARY CHECKS
Verify that no stored codes exist. If emission test shows excessive CO and HC, check items that cause vehicle to run rich. If emission test shows excessive NOx, check items that cause vehicle to run lean or too hot.

PROBABLE CAUSE	CORRECTIVE ACTION
Cooling system malfunction	If the Service tool indicates a very high coolant temperature and the system is running lean: • Check engine coolant level. • Check engine thermostat for faulty part (always open) or for wrong heat range. • Check fan operation
Fuel system malfunction	If the system is running rich, refer to “Diagnostic Aids” chart on the next page. If the system is running lean refer to “Diagnostic Aids” chart on the next page. Check for properly installed fuel system components. Check fuel pressure.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check spark plugs, plug wires, and ignition components.
Component malfunction	Check for vacuum leaks. Check for contamination for catalytic converter (look for the removal of fuel filler neck restrictor). Check for carbon build-up. Remove carbon with quality engine cleaner. Follow instructions on label. Check for plugged PCV valve. Check for stuck or blocked PCV hose. Check for fuel in the crankcase.

Related MIL Faults:
Low side driver
Fuel adapt faults
EST faults

Diagnostic Aids for Rich / Lean Operation

SERVICE TOOL ITEM	RICH	LEAN
Pre-catalyst O2 A/ D counts	Consistently > 250	Consistently < 170
Pre-catalyst O2 sensor switching between high and low	Always high ADC	Always low ADC
Trim valve duty cycle	> 90%	< 10%
Fuel injector pulse width at idle *	< 1.0 msec	> 8 msec.
Malfunction codes	• Pre-catalyst O2 sensor failed rich	• Pre-catalyst O2 sensor failed lean
Closed loop operation	• Pre-catalyst O2 sensor high	• Pre-catalyst O2 sensor low

(*) The duty cycle injector pulse width criteria for lean or rich operation apply only if the O2 sensor is functioning properly. If the sensor is not operating properly the criteria may be reversed.

Rich Operation

LP (Trim valve duty cycle>90%)

- Inspect hoses from AVV port (port on bottom of mixer) to trim valves and regulator for leaks or blockages, replace as necessary.
- Inspect in-line orifices for blockages (in wye), replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec
- Inspect fuel cone for damage, replace mixer assembly as necessary Gasoline (Injector Pulse Width<1.0 msec)
- Check gasoline fuel pressure
- Check injectors for sticking, replace as necessary

Lean Operation

LP (Trim valve duty cycle<10%)

- Check for vacuum leaks, replace hoses, o-rings, and gaskets as necessary
- Check balance line for blockage, replace as necessary
- Check vapor hose for restrictions, replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Gasoline (Injector Pulse Width>8 msec)

- Check system voltage
- Check fuel pressure
- Check injectors for sticking or obstructions

Chart T-1 Restricted Exhaust System Check

Proper diagnosis for a restricted exhaust system is essential before replacement of any components. The following procedures may be used for diagnosis, depending upon engine or tool used.

Check Atpre - Catalystoxygen (O2) Sensor

1. Carefully remove pre-catalyst oxygen (O2) sensor.

2. Install exhaust backpressure tester or equivalent in place of O2 sensor using Snap-On P/N EEVPV311A kit and YA8661 adapter or Mac tool (see illustration).

3. After completing test described below, be sure to coat threads of O2 sensor with anti-seize compound prior to re-installation.

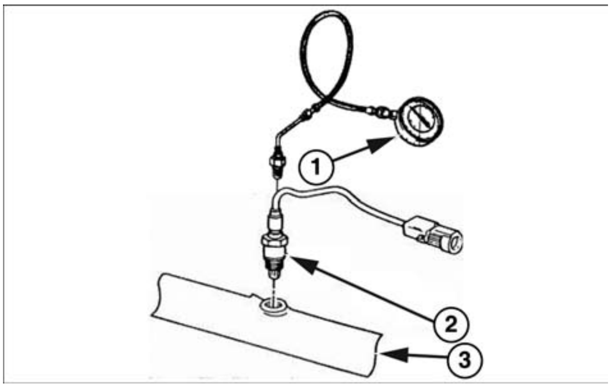


Illustration Notes

1. Backpressure gage

2. Pre-catalyst Oxygen (O2) sensor

3. Exhaust manifold

Diagnosis:

1. With the engine idling at normal operating temperature, observe the exhaust system backpressure reading on the gage. Reading should not exceed 1.25 psig (8.61 kPa).

2. Increase engine speed to 2000 rpm and observe gage. Reading should not exceed 3 psig (20.68 kPa).

3. If the backpressure at either speed exceeds specification, a restricted exhaust system is indicated.

4. Inspect the entire exhaust system for a collapsed pipe, heat distress, or possible internal damage, split welds, or cracked pipe.

5. If there are no obvious reasons for the excessive backpressure, the catalytic converter is restricted and should be replaced using current recommended procedures.

Chapter 9. ADVANCED DIAGNOSTICS

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) as Diagnostic Fault Codes (DFC) or flash codes, and viewed in detail with the use of the Service Tool software. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

Reading Diagnostic Fault Codes

All MI-07 fault codes are three-digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (0.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the end of the code list.

EXAMPLE : A code 461 (ETCSticking) has been detected and the engine has shut down and the MIL has remained ON. When the codes are displayed the MIL will flash four times (4), pause, then flash six times (6), pause, then flash one time (1) This identifies a four sixty one (461), which is the ETCSticking fault. If any additional faults were stored, the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (1), pause, then two flashes (2). This identifies a twelve, signifying the end of the fault list. This list will then repeat.

Displaying Fault Codes (DFC) from SECM Memory

To enter code display mode you must turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal three (3) times within five (5) seconds to enable the display codes feature of the SECM. Simply turn the key OFF to exit display mode. The code list will continue to repeat until the key is turned OFF.

Clearing Fault (DFC) Codes

To clear the stored fault codes from SECM memory you must complete the reset fault pedal maneuver.

⚠ CAUTION

Once the fault list is cleared it cannot be restored.

First turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal ten (10) times within five (5) seconds to clear the fault code list of the SECM. Simply turn the key OFF to exit the reset mode. The code list is now clear and the SECM will begin storing new fault codes as they occur.

Fault Action Descriptions

Each fault detected by the SECM is stored in memory (FIFO) and has a specific action or result that takes place. Listed below are the descriptions of each fault action.

Engine Shutdown: The most severe action is an Engine Shutdown. The MIL will light and the engine will immediately shutdown, stopping spark, closing the fuel lock-off closing, and turning off the fuel pump and fuel injectors.

Delayed Engine Shutdown: Some faults, such as low oil pressure, will cause the MIL to illuminate for 30 seconds and then shut down the engine.

Cut Throttle: The throttle moves to its default position. The engine will run at idle but will not accelerate.

Cut Fuel: Fuel flow will be turned off.

Turn on MIL: The MIL will light by an active low signal provided by the SECM, indicating a fault condition. May illuminate with no other action or may be combined with other actions, depending on which fault is active.

Soft Rev Limit / Medium Rev Limit / Hard Rev Limit: System will follow various sequences to bring engine speed back to acceptable levels.

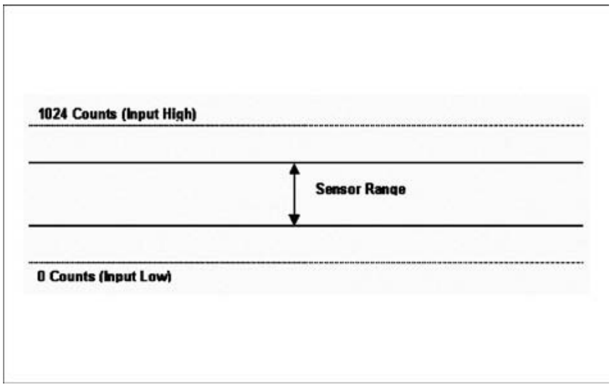
Level4 Power Limit / Level3 Power Limit / Level2 Power Limit / Level1 Power Limit: The maximum engine power output will be limited to one of four possible levels. The engine power is calculated from measured engine parameters (e.g. MAP, rpm, fuel flow, etc).

Disable Gas O2 Control: In LPG mode, closed loop correction of air fuel ratio based on the Pre-catalyst O2 sensor is disabled.

Disable Liquid O2 Control: In Gasoline mode, closed loop correction of air fuel ratio based on the Pre-catalyst O2 sensor is disabled.

Fault List Definitions

All the analog sensors in the MI-07 system have input sensor range faults. These are the coolant temperature sensor, fuel temperature sensor, throttle position sensors, pedal position sensors, manifold pressure sensor, HEGO sensors, and intake air temperature sensor. Signals to these sensors are converted into digital counts by the SECM. A low/high range sensor fault is normally set when the converted digital counts reach the minimum of 0 or the maximum of 1024 (1024 = 5.0 Vdc with ~ 204 counts per volt).



Additionally, the SECM includes software to learn the actual range of the pedal position and throttle position sensors in order to take full advantage of the sensor range. Faults are set if the learned values are outside of the normal expected range of the sensor (e.g. APP1AdaptLoMin).

Table 1. Fault List Definitions

FAULT	DESCRIPTION	CODE (MI04 CODE)
APP1AdaptHiMax	Learned full pedal end of APP1 sensor range higher than expected	641 (64)
APP1AdaptHiMin	Learned full pedal end of APP1 sensor range lowe	651
APP1AdaptLoMax	than expected	661
APP1AdaptLoMin	Learned idle end of APP1 sensor range higher than expected	631 (63)
APP1RangeHigh	Learned idle end of APP1 sensor range lower than expected	621 (62)
APP1RangeLow	APP1 sensor voltage out of range high, normally set if the APP1 signal has shorted to power or the ground for the sensor has opened	611 (61)
APP2AdaptHiMax	APP1 sensor voltage out of range low, normally set if the APP1 signal has shorted to ground, circuit has opened or sensor has failed	642 (68)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
APP2AdaptHiMin	Learned full pedal end of APP2 sensor range lower than expected	652
APP2AdaptLoMax	Learned idle end of APP2 sensor range higher than expected	662
APP2AdaptLoMin	Learned idle end of APP2 sensor range lower than expected	632 (67)
APP2RangeHigh	APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	622 (66)
APP2RangeLow	APP2 sensor voltage out of range low, normally set if the APP2 signal has shorted to ground, circuit has opened or sensor has failed	612 (65)
APP_Sensors_Conflict	APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	691 (69)
CamEdgesFault	No CAM signal when engine is known to be rotating, broken CAM sensor leads or defective CAM sensor	191
CamSyncFault	Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	192
CrankEdgesFault	No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	193
CrankSyncFault	Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	194
ECTOverTempFault	Engine Coolant Temperature is High. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	161 (16)
ECTRangeHigh	Engine Coolant Temperature Sensor Input is High. Normally set if coolant sensor wire has been disconnected or circuit has opened to the SECM.	151 (15)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
ECTRangeLow	Engine Coolant Temperature Sensor Input is Low. Normally set if the coolant sensor wire has shorted to chassis ground or the sensor has failed.	141 (14)
ECT_IR_Fault	Engine Coolant Temperature not changing as expected	171
EST1_Open	EST1 output open, possibly open EST1 signal or defective spark module	421 (42)
EST1_Short	EST1 output shorted high or low, EST1 signal shorted to ground or power or defective spark module	431
EST2_Open	EST2 output open, possibly open EST2 signal or defective spark module	422
EST2_Short	EST2 output shorted high or low, EST2 signal shorted to ground or power or defective spark module	432
EST3_Open	EST3 output open, possibly open EST3 signal or defective spark module	423
EST3_Short	EST3 output shorted high or low, EST3 signal shorted to ground or power or defective spark module	433
EST4_Open	EST4 output open, possibly open EST4 signal or defective spark module	424
EST4_Short	EST4 output shorted high or low, EST4 signal shorted to ground or power or defective spark module	434
EST5_Open	EST5 output open, possibly open EST5 signal or defective spark module	425
EST5_Short	EST5 output shorted high or low, EST5 signal shorted to ground or power or defective spark module	435
EST6_Open	EST6 output open, possibly open EST6 signal or defective spark module	426
EST6_Short	EST6 output shorted high or low, EST6 signal shorted to ground or power or defective spark module	436
EST7_Open	EST7 output open, possibly open EST7 signal or defective spark module	427

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
EST7_Short	EST7 output shorted high or low, EST7 signal shorted to ground or power or defective spark module	437
EST8_Open	EST8 output open, possibly open EST8 signal or defective spark module	428
EST8_Short	EST8 output shorted high or low, EST8 signal shorted to ground or power or defective spark module	438
ETCSpringTest	Electronic Throttle Control Spring Return Test has Failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. **NOTE:** Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	481 (28)
ETC_Open_Fault	Electronic Throttle Control Driver has failed. Normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	471
ETC_Sticking	Electronic Throttle Control is Sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction; a loose throttle plate or worn components shaft bearings. **NOTE:** Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	461 (26)
FuelSelectConflict	Conflict in fuel select signals, normally set if one or both of the fuel select signals are shorted to ground	181
FuelTempRangeHigh	Fuel Temperature Sensor Input is High. Normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	932

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
FuelTempRangeLow	Fuel Temperature Sensor Input is Low. Normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	931
GasFuelAdaptRangeHi	In LPG mode, system had to adapt lean more than expected	731 (73)
GasFuelAdaptRangeLo	In LPG mode, system had to adapt rich more than expected	721 (72)
GasO2FailedLean	Pre-catalyst O2 sensor indicates extended lean operation on LPG	751
GasO2FailedRich	Pre-catalyst O2 sensor indicates extended rich operation on LPG	771 (77)
GasO2NotActive	Pre-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor, or defective FTVs	741 (74)
GasPostO2FailedRich	Post-catalyst O2 sensor control on LPG has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	772
GasPostO2FailedLean	Post-catalyst O2 sensor control on LPG has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set diagnose, these first and after correcting these faults recheck if this fault sets.	752
GasPostO2Inactive	Post-catalyst O2 sensor control on LPG has sensed the O2 sensor is not responding as expected. If any Pre-O2 sensor faults are set diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	742
Reserved for Future Use		743

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
HbridgeFault_ETC	(Electronic Throttle Control Driver has Failed) Indeterminate fault on Hbridge driver for Electronic Throttle Control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	491 (29)
HardOverspeed	Engine speed has exceeded the third level (3 of 3) of overspeed protection	571 (57)
IATRangeHigh	Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected, the circuit has opened to the SECM, or a short to Vbatt has occurred.	381 (38)
IATRangeLow	Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	371 (37)
IAT_IR_Fault	Intake Air Temperature not changing as expected	391
Inj1Open	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	131
Inj2Open	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	132
Inj3Open	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	133
Inj4Open	Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	134
Inj5Open	Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	135
Inj6Open	Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	136
Inj7Open	Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	137
Inj8Open	Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	138
LSDFault_CSValve	Cold Start Valve Fault, signal has opened or shorted to ground or power or defective cold start valve	713

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
LSDFault_CheckEngine	Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp	714
LSDFault_CrankDisable	Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	715
LSDFault_Dither1	Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	711 (71)
LSDFault_Dither2	Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	712
LSDFault_FuelPump	Fuel Pump Fault, signal has opened or shorted to ground or power or defective fuel pump	716
LSDFault_LockOff	Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	717
LSDFault_MIL	Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	718
LiqFuelAdaptRangeHi	In Gasoline mode, system had to adapt rich more than expected	821
LiqFuelAdaptRangeLow	In Gasoline mode, system had to adapt lean more than expected	831
LiqO2FailedLean	Pre-catalyst O2 sensor indicates extended lean operation on gasoline	851
LiqO2FailedRich	Pre-catalyst O2 sensor indicates extended rich operation on gasoline	871
LiqO2NotActive	Pre-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor	841
LiqPostO2FailedRich	Post-catalyst O2 sensor control on gasoline has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	872
LiqPostO2FailedLean	Post catalyst O2 sensor control on gasoline has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	852

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
LiqPostO2Inactive	Post-catalyst O2 sensor control on gasoline has sensed the O2 sensor is not responding as expected. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	842
Reserved		843
LowOilPressureFault	Low engine oil pressure	521 (52)
MAPRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	342
MAPRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	332
MAPTimeRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	341 (34)
MAPTimeRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	331 (33)
MAP_IR_HI	MAP sensor indicates higher pressure than expected	351
MAP_IR_LO	MAP sensor indicates lower pressure than expected	352
MAP_STICKING	MAP sensor not changing as expected	353
MediumOverspeed	Engine speed has exceeded the second level (2 of 3) of overspeed protection	572
O2RangeHigh	Pre -catalyst O2 sensor voltage out of range high, sensor signal shorted to power	921
O2RangeLow	Pre-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	911
O2_PostCatRangeHigh	Post-catalyst O2 sensor voltage out of range high, sensor signal shorted to voltage source (5V or battery)	922
O2_PostCatRangeLow	Post -catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	912
SensVoltRangeHigh	Sensor reference voltage XDRP too high	561 (56)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
SensVoltRangeLow	Sensor reference voltage XDRP too low	551 (55)
ServiceFault1	Service Interval 1 has been reached	991
ServiceFault2	Service Interval 2 has been reached	992
ServiceFault3	Service Interval 3 has been reached	993
ServiceFault4	Service Interval 4 has been reached—time to replace HEGO sensors	994
ServiceFault5	Service Interval 5 has been reached—time to replace engine timing belt	995
SoftOverspeed	Engine speed has exceeded first level (1 of 3) of overspeed protection	573
TPS1AdaptHiMin	Learned WOT end of TPS1 sensor range lower than expected	271
SysVoltRangeHigh	System voltage too high	541 (54)
SysVoltRangeLow	System voltage too low	531 (53)
TPS1AdaptHiMax	Learned WOT end of TPS1 sensor range higher than expected	251 (25)
TPS1AdaptHiMin	Learned WOT end of TPS1 sensor range lower than expected	271
TPS1AdaptLoMax	Learned closed throttle end of TPS1 sensor range higher than expected	281
TPS1AdaptLoMin	Learned closed throttle end of TPS1 sensor range lower than expected	241 (24)
TPS1RangeHigh	TPS1 sensor voltage out of range high, normally set if the TPS1 signal has shorted to power or ground for the sensor has opened	231 (23)
TPS1RangeLow	TPS1 sensor voltage out of range low, normally set if TPS1 signal has shorted to ground, circuit has opened or sensor has failed	221 (22)
TPS2AdaptHiMax	Learned WOT end of TPS2 sensor range higher than expected	252
TPS2AdaptHiMin	Learned WOT end of TPS2 sensor range lower than expected	272
TPS2AdaptLoMax	Learned closed throttle end of TPS2 sensor range higher than expected	282
TPS2AdaptLoMin	Learned closed throttle end of TPS2 sensor range lower than expected	242
TPS2RangeHigh	TPS2 sensor voltage out of range high, normally set if the TPS2 signal has shorted to power or ground for the sensor has opened	232

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
TPS2RangeLow	TPS2 sensor voltage out of range low, normally set if TPS2 signal has shorted to ground, circuit has opened or sensor has failed	222
TPS_Sensors_Conflict	TPS sensors differ by more than expected amount. **NOTE:** The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly	291
TransOilTemp	Excessive transmission oil temperature	933

Table 2. Diagnostic Fault Codes (Flash Codes)

DFC	PROBABLE FAULT	FAULT ACTION*	CORRECTIVE ACTION FIRST CHECK
12	**NONE** Signifies the end of one pass through the fault list	NONE	None, used as end of the fault list identification
131	**Inj1Open** Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	TurnOnMil	Check INJ1 wiring for an open circuit SECM (Signal) A5 to Injector 1 Pin A Switched 12V to Injector 1 Pin B Check Injector 1 Resistance, 12 to14 ohms (cold)
132	**Inj2Open** Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	TurnOnMil	Check INJ2 wiring for an open circuit SECM (Signal) A8 to Injector 2 Pin A Switched 12V to Injector 2 Pin B Check Injector 2 Resistance, 12 to14 ohms (cold)
133	**Inj3Open** Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	TurnOnMil	Check INJ3 wiring for an open circuit SECM (Signal) A4 to Injector 3 Pin A Switched 12V to Injector 3 Pin B Check Injector 3 Resistance, 12 to14 ohms (cold)
134	**Inj4Open** Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	TurnOnMil	Check INJ4 wiring for an open circuit SECM (Signal) A7 to Injector 4 Pin A Switched 12V to Injector 4 Pin B
135 Not Used	**Inj5Open** Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	None	N/A
136 Not Used	**Inj6Open** Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	None	N/A
137 Not Used	**Inj7Open** Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	None	N/A
138 Not Used	**Inj8Open** Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	None	N/A
141 (14)	**ECTRangeLow** Coolant Sensor failure or shorted to GND	TurnOnMil	Check ECT sensor connector and wiring for a short to GND SECM (Signal) Pin B15 To ECT Pin 3
151 (15)	**ECTRangeHigh** Coolant sensor disconnected or open circuit	(1) TurnOnMil (2) Delayed Engine Shutdown (3) CheckEngineLight	Check if ECT sensor connector is disconnected or for an open ECT circuit SECM (Signal) Pin B15 to ECT Pin 3 SECM (Sensor GND) Pin B1 to ECT Pin 1

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
161 (16)	**ECTOverTempFault** Engine coolant temperature is high. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngineLight	Check coolant system for radiator blockage, proper coolant level and for leaks in the system. Possible ECT short to GND, check ECT signal wiring SECM (Signal) Pin B15 to ECT Pin 3 SECM (Sensor GND) Pin B1 to ECT Pin 1 SECM (System GND) Pin A16, B17 Check regulator for coolant leaks
171	**ECT_IR_Fault** Engine coolant temperature not changing as expected	None	Check for coolant system problems, e.g. defective or stuck thermostat
181	**FuelSelectConflict** Conflict in fuel select signals, normally set if both of the fuel select signals are shorted to ground	TurnOnMil	Check fuel select switch connection for a short to GND SECM (SIGNAL) Pin A12 SECM (SIGNAL) Pin A15 SECM (Sensor GND) Pin B1
191	**CamEdgesFault** No CAM signal when engine is known to be rotating, broken crankshaft sensor leads or defective CAM sensor	None	Check CAM sensor connections SECM (SIGNAL) Pin B10 to CAM sensor Pin 2 SECM (Sensor GND) Pin B1 to CAM sensor Pin 3 Switched 12V to CAM sensor Pin 1 Check for defective CAM sensor
192	**CamSyncFault** Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	None	Check CAM sensor connections SECM (SIGNAL) Pin B10 to CAM sensor Pin 2 SECM (Sensor GND) Pin B1 to CAM sensor Pin 3 Switched 12V to CAM sensor Pin 1 Check for defective CAM sensor
193	**CrankEdgesFault** No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin 3 SECM (Sensor GND) PIN B1 to Crank sensor Pin 2 Switched 12V to Crank sensor Pin 1 Check for defective Crank sensor
194	**CrankSyncFault** Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin 3 SECM (Sensor GND) Pin B1 to Crank sensor Pin 2 Switched 12V to Crank sensor Pin 1 Check for defective Crank sensor

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
221 (22)	**TPS1RangeLow** TPS1 sensor voltage out of range low, normally set if the TPS1 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS1 sensor for an open circuit or short to GND SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
222	**TPS2RangeLow** TPS2 sensor voltage out of range low, normally set if the TPS2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS2 sensor for an open circuit or short to GND SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
231 (23)	**TPS1RangeHigh** TPS1 sensor voltage out of range high, normally set if the TPS1 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS1 sensor wiring for a shorted circuit SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2
232	**TPS2RangeHigh** TPS2 sensor voltage out of range high, normally set if the TPS2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS1 sensor wiring for a shorted circuit SECM Pin B4 (signal) to ETC Pin 5 SECM pin B1 (sensor GND) to ETC Pin 2
241 (24)	**TPS1AdaptLoMin** Learned closed throttle end of TPS1 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 6 (TPS1 SIGNAL) (0.7Ω ± 30%) TPS Pin 3 (PWR) to Pin 6 (TPS1 SIGNAL) (1.4Ω ± 30%)
242	**TPS2AdaptLoMin** Learned closed throttle end of TPS2 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 5 (TPS2 SIGNAL) (1.3KΩ ± 30%) TPS PIN 3 (PWR) to PIN 5 (TPS2 SIGNAL) (0.6KΩ ± 30%)
251 (25)	**TPS1AdaptHiMax** Learned WOT end of TPS1 sensor range higher than expected	None	N/A
252	**TPS2AdaptHiMax** Learned WOT end of TPS2 sensor range higher than expected	None	N/A
271	**TPS1AdaptHiMin** Learned WOT end of TPS1 sensor range lower than expected	None	N/A

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
272	**TPS2AdaptHiMin** Learned WOT end of TPS2 sensor range lower than expected	None	N/A
281	**TPS1AdaptLoMax** Learned closed throttle end of TPS1 sensor range higher than expected	None	N/A
282	**TPS2AdaptLoMax** Learned closed throttle end of TPS2 sensor range higher than expected	None	N/A
291	**TPS_Sensors_Conflict** TPS sensors differ by more than expected amount NOTE: The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	(1) TurnOnMil (2) Engine Shutdown	Perform checks for DFCs 241 & 242
331 (33)	**MAPTimeRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	None	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2k) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2k)
332	**MAPRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnect-ing the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4k Ω- 8.2kΩ)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
341 (34)	**MAPTimeRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	None	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
342	**MAPRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
351	**MAP_IR_HI** MAP sensor indicates higher pressure than expected	None	Check for vacuum leaks. Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
352	**MAP_IR_LO** MAP sensor indicates lower pressure than expected	None	Possible defective TMAP sensor.
353	**MAP_STICKING** MAP sensor not changing as expected	None	Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
371 (37)	**IATRangeLow** Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION, FIRST CHECK
381 (38)	**IATRangeHigh** Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
391	**IAT_IR_Fault** Intake Air Temperature not changing as expected	None	Check connections to TMAP sensor. Check that TMAP sensor is properly mounted to manifold.
421	**EST1_Open EST1** output open, possibly open EST1 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A9 (EST1) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details
422	**EST2_Open EST2** output open, possibly open EST2 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A10 (EST2) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
423	**EST3_Open EST3** output open, possibly open EST3 signal or defective spark module	TurnOnMi	Check coil driver wiring and connector for open circuit SECM Pin A3 (EST3) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
424	**EST4_Open EST4** output open, possibly open EST4 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A6 (EST4) to OEM ignition system. See application manual. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
425	**EST5_Open EST5** output open, possibly open EST5 signal or defective spark module	None	N/A
426	**EST6_Open EST6** output open, possibly open EST6 signal or defective spark module	None	N/A
427	**EST7_Open EST7** output open, possibly open EST7 signal or defective spark module	None	N/A
428	**EST8_Open EST8** output open, possibly open EST8 signal or defective spark module	None	N/A
431	**EST1_Short EST1** output shorted high or low, EST1 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A9 (EST1) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
432	**EST2_Short EST2** output shorted high or low, EST2 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A10 (EST2) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
433	**EST3_Short EST3** output shorted high or low, EST3 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A3 (EST3) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
434	**EST4_Short EST4** output shorted high or low, EST4 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A6 (EST4) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
435	**EST5_Short EST5** output shorted high or low, EST5 signal shorted to ground or power or defective spark module	None	N/A
436	**EST6_Short EST6** output shorted high or low, EST6 signal shorted to ground or power or defective spark module	None	N/A

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
437	**EST7_Short** EST7 output shorted high or low, EST7 signal shorted to ground or power or defective spark module	None	N/A
438	**EST8_Short** EST8 output shorted high or low, EST8 signal shorted to ground or power or defective spark module	None	N/A
461 (26)	**ETC_Sticking** Electronic Throttle Control is sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction, a loose throttle plate, or worn components shaft bearings. NOTE: The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly	(1)TurnOnMil (2) EngineShutdown (3)CutThrottle	Check for debris or obstructions inside the throttle body Check throttle-plate shaft for bearing wear Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0
471	**ETC_Open_Fault** Electronic Throttle Control Driver has failed, normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	None	Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0
481 (28)	**ETCSpringTest** Electronic Throttle Control Driver has failed, normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective. Electronic Throttle Control Spring Return Test has failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. NOTE: The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	(1) TurnOnMil (2) EngineShutdown	Perform throttle spring test by cycling the ignition key and re-check for fault

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
491 (29)	**HbridgeFault_ETC** Electronic Throttle Control Driver has failed. Indeterminate fault on Hbridge driver for electronic throttle control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	TurnOnMil	Check ETC driver wiring for a shorted circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0Ω
521 (52)	**LowOilPressureFault** Low engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngine Light	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 to Oil Pressure Switch
531 (53)	**SysVoltRangeLow** System voltage too low	TurnOnMil	Check battery voltage • Perform maintenance check on electrical connections to the battery and chassis ground • Check battery voltage during starting and with the engine running to verify charging system and alternator function • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)
541 (54)	**SysVoltRangeHigh** System voltage too high	TurnOnMil	Check battery and charging system voltage •Check battery voltage during starting and with the engine running •Check voltage regulator, alternator, and charging system •Check battery and wiring for overheating and damage • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
551 (55)	**SensVoltRangeLow** Sensor reference voltage XDRP too low	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 XDRP +5 Vdc to TMAP Pin 1 XDRG GND Verify transducer power at the SECM with a multimeter SECM Pin B24 +5 Vdc to SECM Pin B1 XDRG GND Verify transducer power at ETC with a multimeter ETC Pin 3 XDRP PWR to ETC Pin 2 XDRG GND Verify transducer power to the foot pedal with a multimeter.
561 (56)	**SensVoltRangeHigh** Sensor reference voltage XDRP too high	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 XDRP +5 Vdc to TMAP Pin 1 XDRG GND Verify transducer power at the SECM with a multimeter SECM Pin B24 +5 Vdc to SECM Pin B1 XDRG GND Verify transducer power at ETC with a multimeter ETC Pin 3 XDRP PWR to ETC Pin 2 XDRG GND Verify transducer power to the foot pedal with a multimeter.
571 (57)	**HardOverspeed** Engine speed has exceeded the third level (3 of 3) of overspeed protection	(1) TurnOnMil (2) HardRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
572	**MediumOverspeed** Engine speed has exceeded the second level (2 of 3) of overspeed protection	(1) TurnOnMil (2) MediumRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
573	**SoftOverspeed** Engine speed has exceeded the first level (1 of 3) of overspeed protection	(1) TurnOnMil (2) SoftRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
611 (61)	**APP1RangeLow** APP1 sensor voltage out of range low, normally set if the APP1 signal has shorted to ground, circuit has opened or sensor has failed	(1) TurnOnMil (2) CheckEngineLight	Check foot pedal connector Check APP1 signal at SECM PIN B7

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
612 (65)	**APP2RangeLow** APP2 sensor voltage out of range low, normally set if the APP2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check foot pedal connector • Check APP2 signal at SECM PIN B16
621 (62)	**APP1RangeHigh** APP1 sensor voltage out of range high, normally set if the APP1 signal has shorted to power or the ground for the sensor has opened	(1) TurnOnMil (2) CheckEngine Light	Check foot pedal connector • Check APP1 signal at SECM PIN B7
622 (66)	**APP2RangeHigh** APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check foot pedal connector • Check APP2 signal at SECM PIN B16
631 (63)	**APP1AdaptLoMin** Learned idle end of APP1 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP1 signal at SECM Pin B7
632 (67)	**APP2AdaptLoMin** Learned idle end of APP2 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP2 signal at SECM Pin B16
641 (64)	**APP1AdaptHiMax** Learned full pedal end of APP1 sensor range higher than expected	None	N/A
642 (68)	**APP2AdaptHiMax** Learned full pedal end of APP2 sensor range higher than expected	None	N/A
651	**APP1AdaptHiMin** Learned full pedal end of APP1 sensor range lower than expected	None	N/A
652	**APP2AdaptHiMin** Learned full pedal end of APP2 sensor range lower than expected	None	N/A
661	**APP1AdaptLoMax** Learned idle end of APP1 sensor range higher than expected	None	N/A
662	**APP2AdaptLoMax** Learned idle end of APP2 sensor range higher than expected	None	N/A
691 (69)	**APP_Sensors_Conflict** APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	(1) TurnOnMil (2) Level1PowerLimit	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP1 signal at SECM Pin B7 • Cycle the pedal several times and check APP2 signal at SECM Pin B16

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
711 (71)	**LSDFault_Dither1** Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	TurnOnMil	Check FTV1 for an open wire or FTV connector being disconnected FTV1 Pin 1 (signal) to SECM Pin A1 FTV1 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV1 for an open coil by disconnecting the FTV connector and measuring the resistance (~26 Ω ± 2 Ω)
712	**LSDFault_Dither2** Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	TurnOnMil	Check FTV1 for an open wire or FTV connector being disconnected or signal shorted to GND FTV2 Pin 1 (signal) to SECM Pin A2 FTV2 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV1 for an open coil by disconnecting the FTV connector and measuring the resistance (~26 Ω ± 2 Ω)
714	**LSDFault_CheckEngine** Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp	None	Check 'Check Engine Lamp' for an open wire or shorted to GND
715	**LSDFault_CrankDisable** Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	None	N/A
717	**LSDFault_LockOff** Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	TurnOnMil	Check fuel lock off valve for an open wire or connector being disconnected or signal shorted to GND Lockoff Pin B (signal) to SECM Pin A11 Lockoff Pin A (power) to SECM (DRVP) Pin A23 Check CSV for an open coil by disconnecting the CSV connector and measuring the resistance (~26 Ω ± 3 Ω)
718	**LSDFault_MIL** Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	None	Check MIL lamp for an open wire or short to GND.
721 (72)	**GasFuelAdaptRangeLo** In LPG mode, system had to adapt rich more than expected	TurnOnMil	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose Check for missing orifice(s).

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
731 (73)	**GasFuelAdaptRangeHi** In LPG mode, system had to adapt lean more than expected	TurnOnMil	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
741 (74)	**GasO2NotActive** Pre-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor	(1) TurnOnMil (2) DisableGas O2Ctrl	Check that Pre-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B13 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to SECM (DRVP + 12V) Pin A23 Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
742	**GasPostO2NotActive** Post-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor.	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Check that Post-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B19 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to Post O2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O2 heater. Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
743	Reserved		
751	**GasO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose. Check for missing orifice(s).
752	**GasPostO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Correct other faults that may contribute to 752 (e.g. faults pertaining to dither valves, Pre-Cat O2, Post Cat O2 sensor) Check for vacuum leaks Check for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
771 (77)	**GasO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
772	**GasPostO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGasPostO2Ctrl	Correct other faults that may contribute to 772 (e.g. faults pertaining to FTVs, Pre-Cat O2, Post Cat O2 sensor) Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
821	**LiqFuelAdaptRangeHi** In Gasoline mode, system had to adapt lean more than expected	TurnOnMil	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector.
831	**LiqFuelAdaptRangeLow** In Gasoline mode, system had to adapt rich more than expected	TurnOnMil	Low gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector.
841	**LiqO2NotActive** Pre-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check that Pre-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B13 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to SECM (DRVP + 12V) PIN A23 Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
842	**LiqPostO2NotActive** Post-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor.	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Check that Post-catalyst O2 sensor connections are OK. O2 (return) Pin 4 to SECM Pin B1 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to Post O2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O2 heater. Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
843	Reserved		
851	**LiqO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector
852	**LiqPostO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Correct other faults that may contribute to 852 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O2, Post Cat O2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
871	**LiqO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	High gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector
872	**LiqPostO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiqPostO2Ctrl	Correct other faults that may contribute to 872 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O2, Post Cat O2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
911	**O2RangeLow** Pre-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O2 sensor installed before the catalyst is shorted to GND or sensor GND. O2 (signal) Pin 3 to SECM Pin B13 SECM (DRVG GND) Pins A16, B17 SECM (XDRG sensor GND) Pin B1
912	**O2_PostCatRangeLow** Post-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post catalyst O2Ctrl (3) Disable LPG Post catalyst O2Ctrl	Check if O2 installed after the catalyst sensor is shorted to GND or sensor GND. O2 (signal) Pin 3 to SECM Pin B19 Possible sources: SECM (DRVG GND) Pins A16, B17 and SECM (XDRG sensor GND) Pin B1
921	**O2RangeHigh** Pre-catalyst O2 sensor voltage out of range high, sensor signal shorted to power	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O2 sensor installed before catalyst is shorted to +5Vdc or battery. O2 (signal) Pin 3 to SECM Pin B13 SECM (XDRP + 5V) Pin B24 SECM (DRVP + 12V) Pin A23
922	O2_PostCatRangeHigh Post-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post catalyst O2Ctrl (3) Disable LPG Post catalyst O2Ctrl	Check if O2 sensor installed after catalyst is shorted to +5Vdc or battery. O2 (signal) Pin 3 to SECM Pin B19 Possible voltage sources: SECM (XDRP + 5V) Pin B24 and SECM (DRVP + 12V) Pin A23
931	**FuelTempRangeLow** Fuel Temperature Sensor Input is Low normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check fuel temp sensor connector and wiring for a short to GND SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2 SECM (system GND) Pin A16, B17
932	**FuelTempRangeHigh** Fuel Temperature Sensor Input is High normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check if fuel temp sensor connector is disconnected or for an open FTS circuit SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
933	**TransOilTemp** Excessive transmission oil temperature	(1) TurnOnMil (2) Delayed EngineShutdown	Refer to drivetrain manufacturer's transmission service procedures
991	**ServiceFault1** Service Interval 1 has been reached	None	Perform service procedure related to Service Interval 1 (determined by OEM)
992	**ServiceFault2** Service Interval 2 has been reached	None	Perform service procedure related to Service Interval 2 (determined by OEM)
993	**ServiceFault3** Service Interval 3 has been reached	None	Perform service procedure related to Service Interval 3 (determined by OEM)
994	**ServiceFault4** Service Interval 4 has been reached—replace HEGO sensors	TurnOnMil	Replace Pre-catalyst HEGO sensor Replace Post-catalyst HEGO sensor
995	**ServiceFault5** Service Interval 5 has been reached—replace timing belt	TurnOnMil	Replace engine timing belt

(*) Fault actions shown are default values specified by the OEM.

Appendix

Service Tool Software (MotoView)

Service Tool Software Kit

Service tool software kit consists of USB-CAN converter, Service tool software (MotoView) and Extension cable.

A343079
USB (Universal Serial Bus) to CAN (Controller Area Network) Converter Assembly

A343080
Service Tool Software (includes CD and Crypt Token (License Dongle))

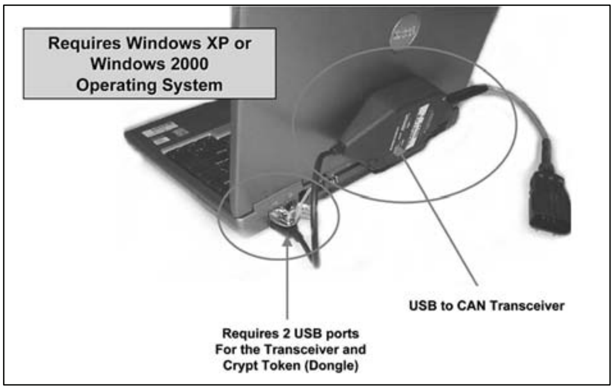
A334071
Extension Cable (L=200 cm)

A334082
Extension Cable (L=20 cm)

Service Tool Connection to SECM

Communications to the SECM from the Service Tool is through a CAN port using a two wire connection. High-speed CAN reaches 1Mbps and is used for engine control and power-train applications.

Laptop Computer Running Service Tool Software



Service Tool Display

Service Tool Display consists of Service Screen, Fault Screen, Ground speed select option, Fault list and Override screen.

Service Screen

Key parameters of a running engine are grouped together for easy reference in the ENGINE block.

ENGINE		
RPM	752.00	
Engine State	Run	
LP Fuel Select	Enabled	
Gasoline Select	Disabled	
Lock Off	1	1=ON
Fuel Pump		1=ON
Indicated Torque	80.14	
Ground Speed Switch	0	0=CLOSED
Post Cat O2 Heater Relay	Enabled	
Cold Start Enabled	Disabled	

Parameters specific to Air/Fuel Ratio Control are displayed in the AFR block.

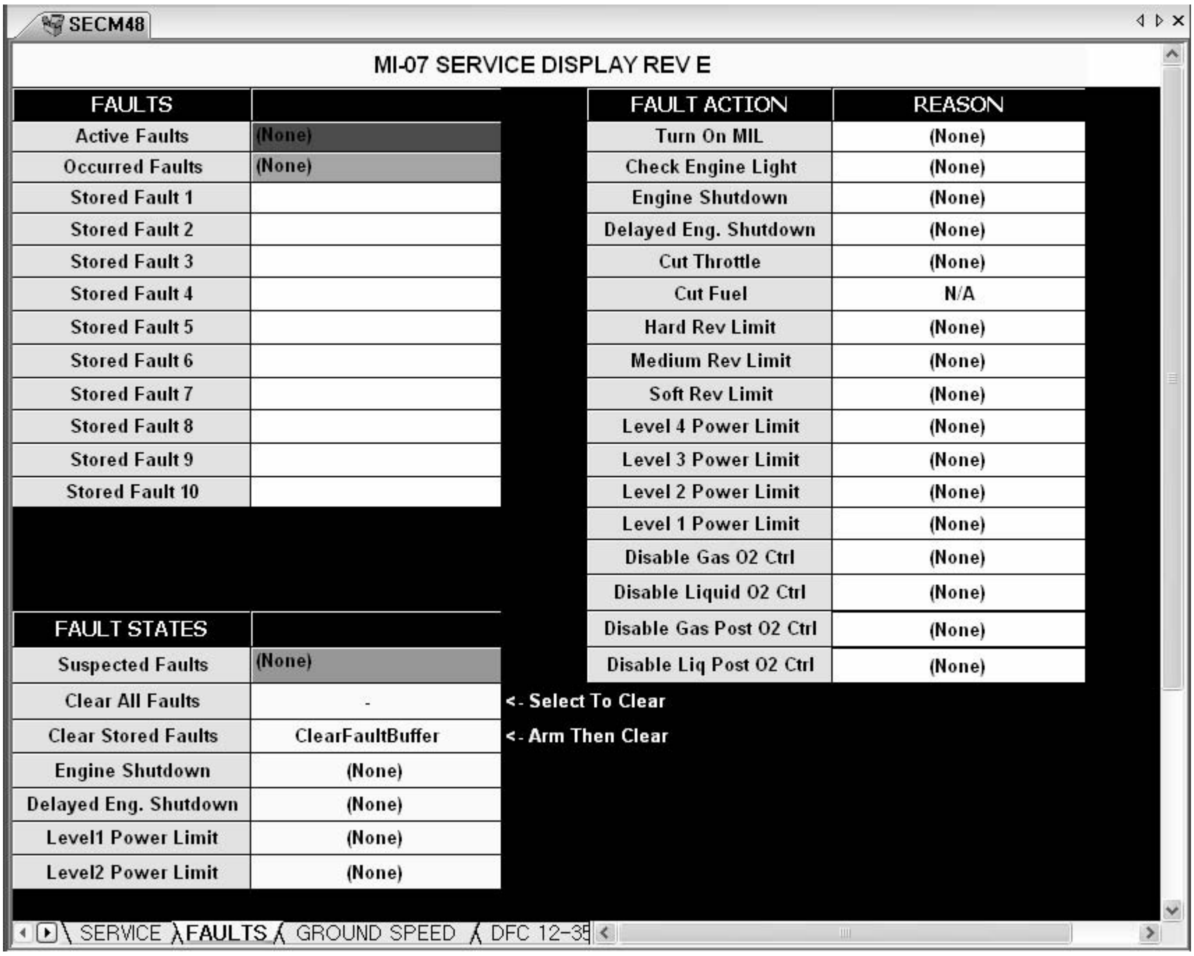
AFR CONTROL	LP	
LP Pre Cat O2 Fuel Cntrl	Closed-Loop	
Duty Cycle %	45.92	
LP Adapt Offset	0.14	
Mass Airflow	3.11	
Pre Catalyst O2 Value	1.00	Phi
Post Catalyst O2 Value	0.95	Phi
LPG Post Cat Adapt	0.0000	

Throttle and Foot Pedal parameters are displayed together in the CNTRL Block

THROTTLE/PEDAL	
Throttle Position Setpoint	11.81
TPS1 %	11.73
TPS2 %	12.29
APP1 %	0.00
APP2 %	0.00

Fault Screen

Active faults are displayed as they are occurring.
They ability to clear faults
A fault history list of all 10 fault records
Fault records are recorded as FIFO (First In First Out)
Once a fault is recorded a repeat of the same fault will not be written to the history list
Flash Codes begin at record 1 not record 10



Ground Speed Select Option

Speed Limits are set by entering RPM values in the red boxes
Values are restricted by Upper and Lower Limits

GROUND SPEED SELECT OPTION		
ENGINE		
RPM	750.00	
Engine State	Run	
LP Fuel Select	Enabled	
Gasoline Select	Disabled	
Lock Off	1	1=ON
Fuel Pump		1=ON
Indicated Torque	79.40	
Ground Speed Switch	0	0=CLOSED
Post Cat O2 Heater Relay	Enabled	
Cold Start Enabled	Disabled	
GROUND SPEED RPM SETPOINTS		OPE
SWITCHED MAX RPM	2000.00	**Maximum RPM wh
HIGH MAX RPM	2600.00	**Maximum RPM wh depressed. NOTE: and should be set a
** DEFAULT SETPOINTS ARE 3500 RPM		

Fault List

A FAULT LIST screen provides a complete list of faults including Fault Codes with monitored parameters so the technician does not have to refer to the manual for fault descriptions or codes while using the service tool.

DFC	FAULT	ACTIVE ACTION	DESCRIPTION
12	NONE	NONE	Signifies the end of one pass through the fault list
131	Inj1Open	TurnOnMIL	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector
132	Inj2Open	TurnOnMIL	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector
133	Inj3Open	TurnOnMIL	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector
134	Inj4Open	TurnOnMIL	Gasoline Injector 4 open circuit, broken injector 3 wire or defective injector
135	N/A	N/A	
136	N/A	N/A	
137	N/A	N/A	
138	N/A	N/A	
141	ECTRangeLow	TurnOnMIL	Coolant Sensor failure or shorted to GND
151	ECTRangeHigh	DelayEngineShutdown	Coolant sensor disconnected or open circuit
161	ECTOverTempFault	DelayEngineShutdown	Engine coolant temperature is high. The sensor has measured an excessive coolar
171	ECT_IR_Fault	TurnOnMIL	Engine coolant temperature not changing as expected
181	FuelSelectConflict	TurnOnMIL	Conflict in fuel select signals, normally set if one or both of the fuel select signals a
191	CamEdgesFault	NONE	No CAM signal when engine is known to be rotating.
192	CamSyncFault	NONE	Loss of synchronization on the CAM sensor, an intermittent connection on the CAM
193	CrankEdgesFault	NONE	No crankshaft signal when engine is known to be rotating, broken crankshaft sens
194	CrankSyncFault	NONE	Loss of synchronization on the crankshaft sensor, normally due to an intermittent c
221	TPS1RangeLow	TurnOnMIL	TPS1 sensor voltage out of range low, TPS1 signal has shorted to ground, circuit h
222	TPS2RangeLow	TurnOnMIL	TPS2 sensor voltage out of range low, TPS2 signal has shorted to ground, circuit h
231	TPS1RangeHigh	TurnOnMIL	TPS1 sensor voltage out of range high, TPS1 signal has shorted to power or the gr
232	TPS2RangeHigh	TurnOnMIL	TPS2 sensor voltage out of range high, TPS2 signal has shorted to power or the gr
241	TPS1AdaptLoMin	NONE	Learned closed throttle end of TPS1 sensor range lower than expected
242	TPS2AdaptLoMin	NONE	Learned closed throttle end of TPS2 sensor range lower than expected

Override Screen

1. Click on the Manual Value for the component.

2. Enter a new manual value that will be used when manually overriding the component.

3. Click the Override Select box for the component

4. Select “Pass-Through” for normal operation or “Override” to manually control the component.

⚠ WARNING

Be aware of fuel flow and ignition during manual mode or engine damage may result.

Battery Power	Status	Manual Value	Override Select
Main Power Relay	Enabled	Off	Pass-Through

Lock-Off (LP)	Status (1=Open)	Manual Value	Override Select
Fuel Lock-Off (LP)	1	0	Pass-Through

Fuel Select (Gasoline)	Status (1=ON)	Manual Value	Override Select
Fuel Select Switch	0	0	Pass-Through

Fuel Pump (Gasoline)	Status (1=ON)	Manual Value	Override Select
Electric Fuel Pump	0	0	Pass-Through

AFR Trim Valves	Status (DC %)	DC OFFSET	Lock DC %
FTVs Duty Cycle	42.50	0.00	Unlocked

Oxygen Sensor	Status	Manual Value	Override Select
Post Cat O2 Heater Relay	Enabled	0	Pass-Through

Cold Start Valve	Status (DC %)	Manual Value	Override Select
CSV	1.00	0.00	Pass-Through

SECM field update with Service Tool

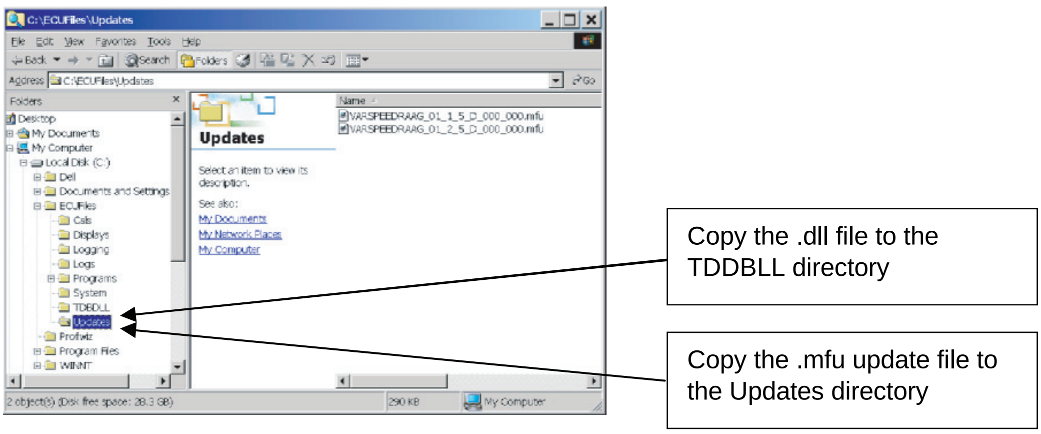
SECM controllers can be upgraded in the field using MotoUpdate software. Typically, MotoUpdate and MotoViewer applications are packaged together in the MotoService software application. Software upgrade files may be released to the field to enhance performance, provide additional features, and/or correct software problems.

This document provides step-by-step instructions for upgrading a SECM using MotoUpdate software. In order to illustrate the process, the following example upgrade is used throughout this document.

Current SECM software version:
VARSPEDDRAAF-01-2-5-D-000-000.siz (calibration ID)
Upgrade to software version:
VARSPEDDRAAG-01-2-5-D-000-000.siz (calibration ID)
Using field update file:
VARSPEDDRAAG -01-1-5-D-000.mfu
NEW Corresponding DLL file:
VARSPEDDRAAG.dll

STEP1 - LOAD UPDATE FILES INTO THE APPROPRIATE DIRECTORY

Software upgrade packages include an upgrade file (.mfu) and translation file (.dll). The (.mfu) file is required to upgrade the module, and the (.dll) is required by MotoViewer software to communicate with the module after the upgrade. Therefore, both files are provided together. Copy the field update file (.mfu) to the C:/ECUF Files/Updates directory, and the corresponding (.dll) file to C:/ECU Files/TDBDLL.

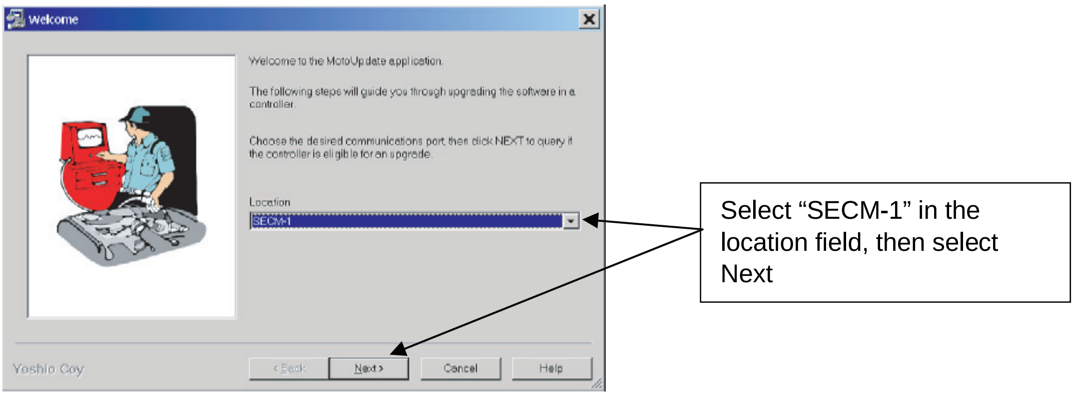


STEP 2 - CONNECT THE COMPUTER

Prior to launching the MotoUpdate software, a valid Criptoken must be installed in one of the available USB ports on the update computer. A second available USB port will be used by the USB to CAN converter. The USB to CAN coverter must then be connected to the SECM. (A USB hub must be used with computers that do not have two USB ports).

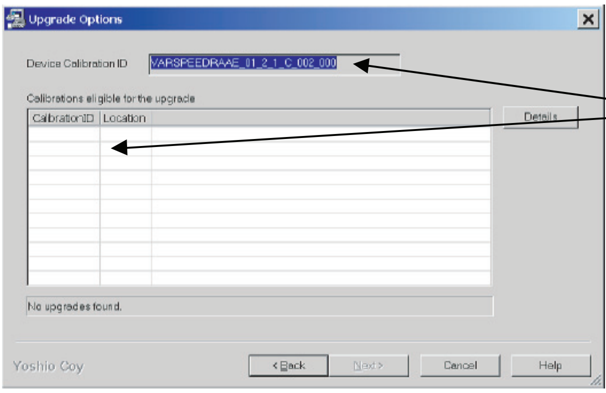
STEP 3 - LAUNCH THE MOTOUPDATE APPLICATION

Launch the MotoUpdate application. You will see a Welcome scree.



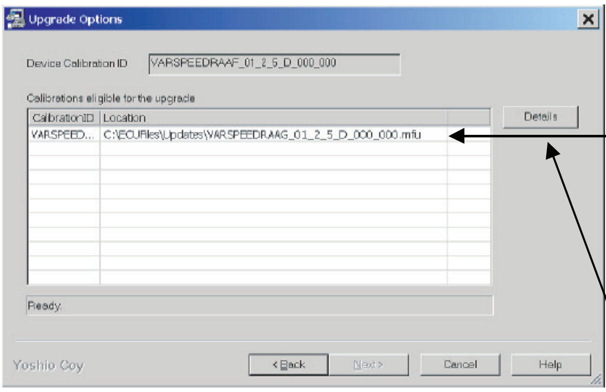
The next screen will provide a list of all of the available software upgrades available for the current engine, based upon what update files have been placed in the "Update" directory (as shown in Step-1 above). Please note that during this process, the software must query the SECM for the current software version, and therefore, the computer must be connected to the SECM and the ignition key must be in the ON position.

In general, it is usually best to see the latest revision (e.g. 001 is later than 000) in situations where multiple revisions are available. Additional information is provided in the revision matrix and/or service bulletins.



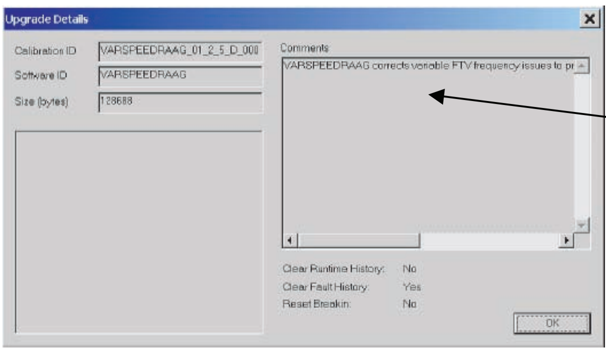
This Upgrade Options screen shows that there are no upgrades available for the listed Calibration ID. Note: If no upgrades are shown, consult the revision matrix for latest software versions.

No Upgrader Available for this Engine



This calibration ID has one (1) available upgrade

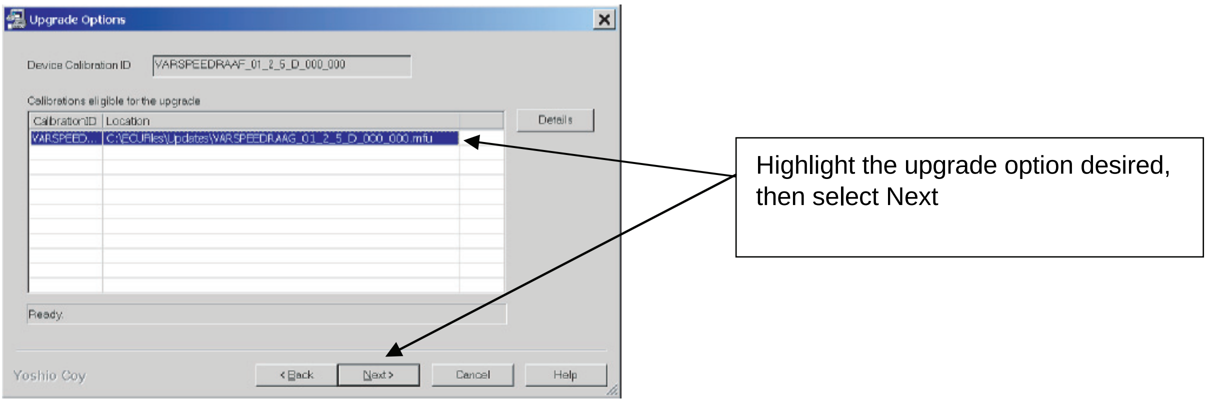
No Upgrader Available for this Engine



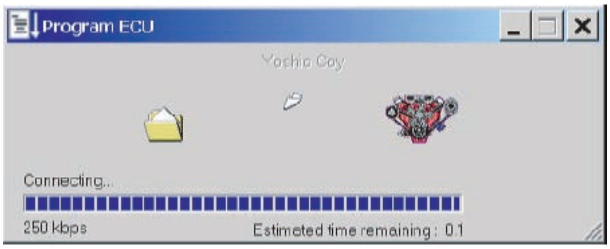
Selecting the "Details" button on the pervious screen will bring up the Upgrade Details screen

STEP 4 - PROGRAM THE MODULE

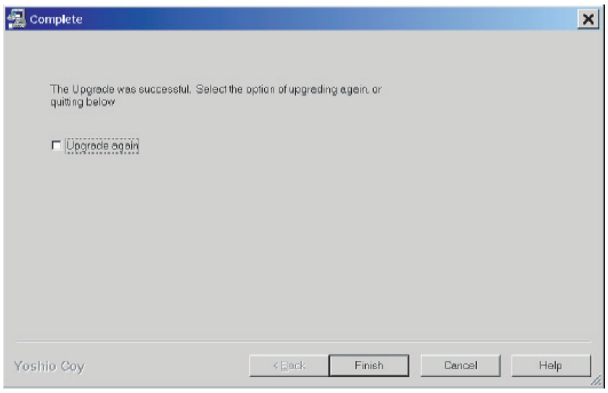
Once the desired upgrade is located and highlighted, select Next to upgrade ithe module.



Follow the on-screen instructions to complete the update process. Once the programming process begins, it must run to completion. If power is interrupted or the process fails, the SECM may be rendered unusable. Several update screens will provide a running status of the upgrade process, as shown below.



Once the upgrade process is complete, a “complete” message will appear and will give the operator the option of upgrading another module. If another module is to be upgraded, select the “Upgrade again” button and select next. If another upgrade is not required, select finish.



Note 1: After successfully upgrading the SECM, MotoViewer software will not function without the appropriate translation file (.dll) discussed in Step-1 above.

Note 2: If the programming is unsuccessful, the programming process may be repeated. If repeatedly unsuccessful, please contact .

Ground Speed Limits (Option)

The maximum allowable speed of Doosan forklifts is an optional feature that can be easily activated using the MotoView service tool. This feature is very useful to customers with indoor warehouse operations.

Here's how you can activate the speed-limiting feature.

1) Install Speed control option onto the trucks

2) Set the new speed limit using the MotoView Service tool, if required.

HOW TO INSTALL SPEED LIMIT OPTION

1) Switch assy-pressure

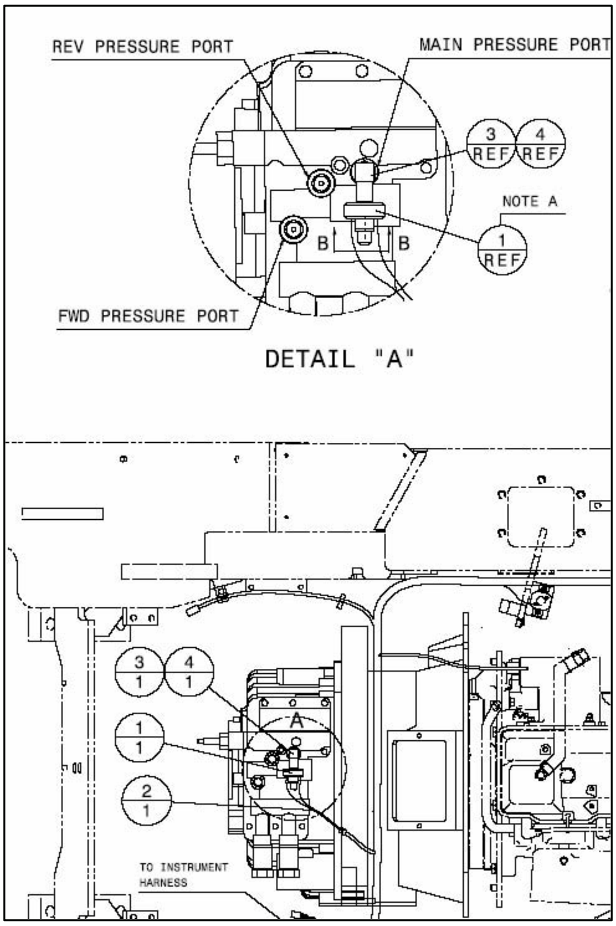
2) Jumper Harness assy

3) Elbow

4) O-ring

1. Assemble the pressure switch assy onto the main pressure port of transmission using elbow and o-ring like [Figure 1].

2. Assemble the harness assy between the pressure switch and engine wiring harness.



[Figure 1] Speed control option

How To Set New Speed Limit

Default Engine Maximum Speed

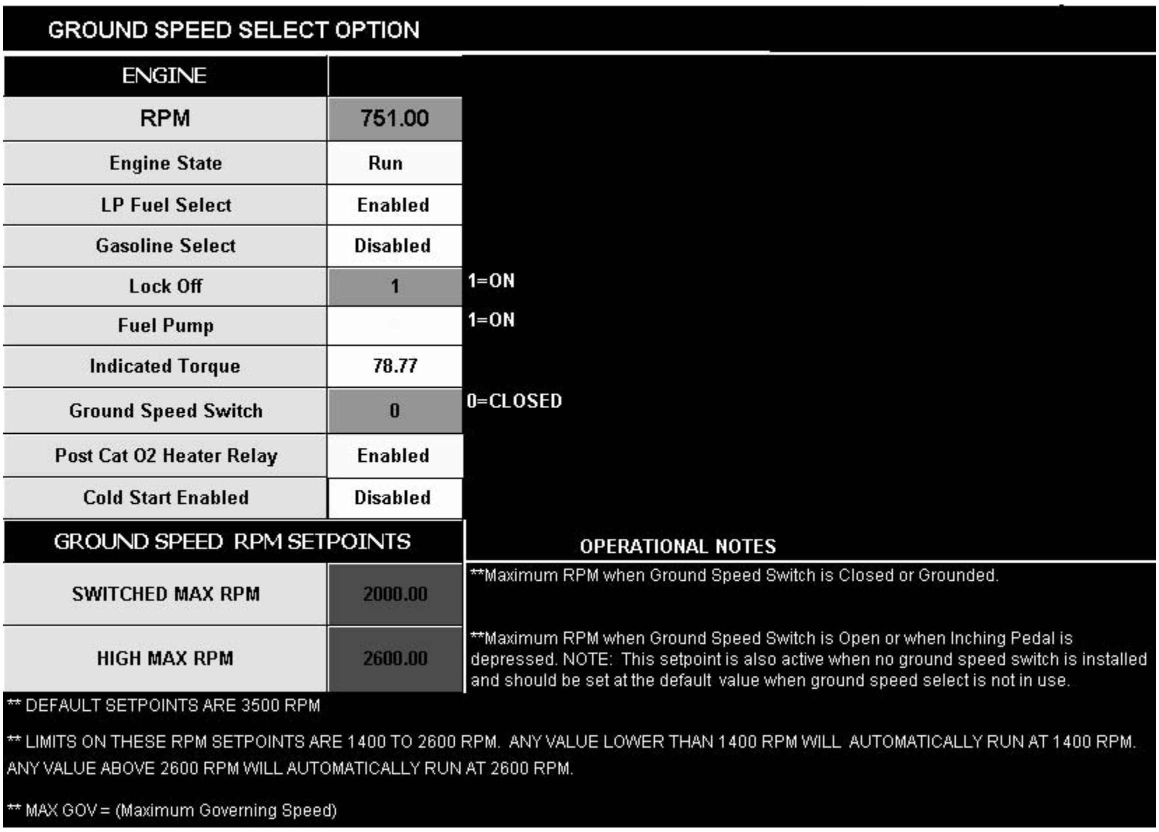
Once speed control option is assembled, the default engine maximum speed is as followed;

Forklift Model	Engine Model	Engine max. speed (rpm)	
		Neutral	In-Gear
G(C)15/18S-5 G(C)20SC-5	G420F(E)	2,450	2,000
G(C)20/25/30E-5	G420F(E)	2,600	2,000
G(C)20/25/30/33P-5 G35C-5	G424F(E)	2,600	2,000
G(C)35/40/45S-5 G(C)50/55C-5 G50/60/70S-5	G643(E)	2,500	2,000

Note :
Neutral: The inching pedal is pressed by a driver.
In-Gear: The inching pedal is NOT pressed by a driver.

How to Set New Speed Limit

Maximum RPM for both the **NEUTRAL** state (Normal) and **IN-GEAR** state (Speed Limiting) are configurable using the MotoView Service Tool.



[Figure 2] Ground Speed Select Screen of the MotoView Service Tool

[Figure 2] shows the Speed Limit screen of the MotoView service tool. The green boxes are configurable for both the NEUTRAL MAX RPM Setpoint and the IN-GEAR MAX RPM Setpoint. The pressure switch state is displayed at the bottom of the screen and labeled NEUTRAL SWITCH STATE.

For example, as Figure 2 depicts:

With pushing of inching pedal, the maximum RPM for normal speed governing (Neutral State) is set at 2600.

With release of inching pedal, the maximum RPM for limited speed governing (In-Gear State) is set at 2000.

<u>Allowable Range of RPM Limits</u>

Software limits of both Neutral and In-Gear are displayed on the right side of the Speed Limit screen. Values that are entered in the configurable "green boxes" cannot exceed the upper limit value or fall below the lower limit value.

LPG And LPG Fuel Tanks

LPG Fuel Supply

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylenes in various mixtures. LPG is produced as a by-product of natural gas processing or it can be obtained from crude oil as part of the oil refining process. LPG, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons.

In its natural state, propane is colorless and odorless; an odorant (ethyl mercaptan) is added to the fuel so its presence can be detected. There are currently three grades of propane available in the United States. A propane grade designation of HD5 (not exceeding 5% propylene), is used for internal combustion engines while much higher levels of propylene (HD10) are used as commercial grade propane along with a commercial propane /butane mixture.

APPROXIMATE COMPOSITION OF HD5 PROPANE BY VOLUME

Propane (C3H8)	Propy lene	Butane (C4H10)	Iso-Butane	Methane (CH4)	TOTAL
90.0% min.	5% max.	2.0%	1.5%	1.5%	100%

An advantage of LPG is the ability to safely store and transport the product in the liquid state. In the liquid state propane is approximately 270 times as dense as it is in a gaseous form. By pressurizing a container of LPG we can effectively raise the boiling point above –44 deg. C / -42 deg. C, keeping the propane in liquid form. The point at which the liquid becomes a gas (boiling point) depends on the amount of pressure applied to the container.

This process operates similarly to an engine coolant system where water is kept from boiling by pressurizing the system and adding a mixture of glycol. For example water at normal atmospheric pressure will boil at 212 deg. F / 100 deg. C. If an engines operating temperature is approximately 230 deg. F / 110 deg. C, then the water in an open un-pressurized cooling system would simply boil off into steam, eventually leaving the cooling system empty and over heating the engine. If we install a 10 PSIG cap on the radiator, pressurizing the cooling system to 10 PSIG, the boiling point of the water increases to 242 deg. F / 117 deg. C, which will cause the water to remain in liquid state at the engines operating temperature.

The same principle is applied to LPG in a container, commonly referred to as an LPG tank or cylinder. Typically an LPG tank is not filled over 80% capacity allowing for a 20% vapor expansion space. Outside air temperature effect's an LPG tank and must be considered when using an LPG system. (Figure 2) shows the relationship between pressure and temperature in a LPG tank at a steady state condition.

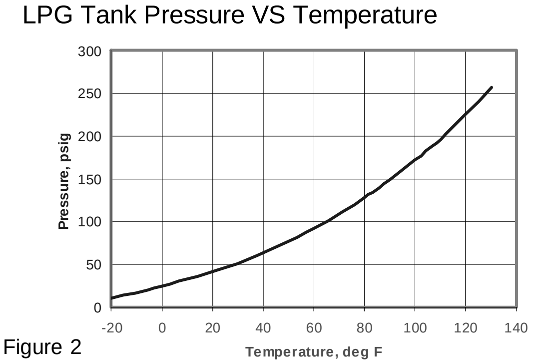


Figure 2

With 128 PSIG vapor pressure acting against the liquid propane the boiling point has been raised to slightly more than 80 deg. F / 27 deg. C.

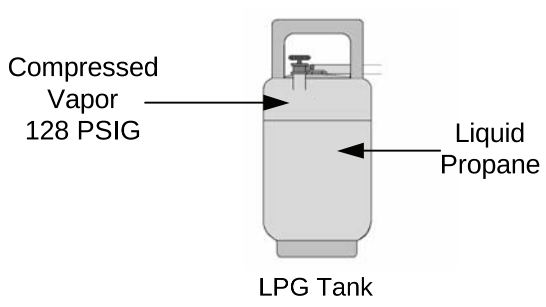


Figure 3

NOTE: Vapor pressure inside an LPG tank depends on the ambient air temperature outside the tank, not the amount of liquid inside the tank. A tank that is ¾ full of liquid propane at 80 deg. F will contain the same vapor pressure as a tank that is only ¼ full of liquid propane.

LPG's relative ease of vaporization makes it an excellent fuel for low-rpm engines on start-and-stop operations. The more readily a fuel vaporizes the more complete combustion will be.
Because propane has a low boiling point (-44F), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little, if any, carbon build up.

LPG Fuel Tanks

The two styles of LPG storage containers available for industrial use and lift truck applications are portable universal cylinders and permanently mounted tanks. Portable universal cylinders are used primarily for off-highway vehicles and are constructed in accordance with the DOT-TC (United States Department of Transport – Transport Canada). The cylinders are referred to as universal because they can be mounted in either a vertical or horizontal position (Figure 4).

Figure 4

NOTE: A 375-psig, relief valve is used on a DOT forklift tank. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over.

Installing LPG Fuel Tanks

When installing a tank on a lift truck, the tank must be within the outline of the vehicle to prevent damage to the valves when maneuvering in tight spaces. Horizontal tanks must be installed on the saddle that contains an alignment pin, which matches the hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom of the tank. A common problem is that often these guide-pins are broken off, allowing the tank to be mounted in any position. This creates two problems. 1). When the liquid withdrawal tube is exposed to the vapor space, it may give a false indication that the tank is empty, when it actually is not. 2). The safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem,

⚠ CAUTION

When empty, the tank is exchanged with a pre-filled replacement tank. When exchanging a tank, safety glasses and gloves should be worn.

LPG Fuel Tank Components

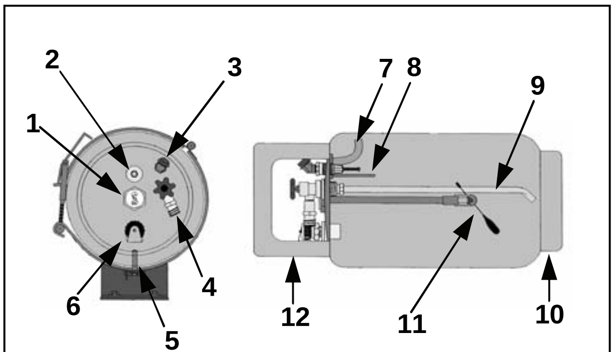


Figure 5

(1) Fuel Gauge (2) 80% Stop Bleeder
(3) Pressure Relief Valve
(4) Service Valve (Tank end male coupling) (5) Filler Valve
(6) Alignment Pin
(7) Vapor Withdrawal Tube (Only used with Vapor Withdrawal)
(8) 80% Limiter Tube (9) Liquid Withdrawal Tube
(10) Foot Ring (11) Fuel Level Float (12) Collar

Fuel Gauge

In figure 5 a visual fuel gauge is used to show the fuel level in the tank. A mechanical float mechanism detects the liquid propane level. A magnet on the end of the float shaft moves a magnetic pointer in the fuel gauge. Some units have an electronic sending unit using a variable resistor, installed in place of a gauge for remote monitoring of the fuel level. The gauge may be changed with fuel in the tank. **DO NOT REMOVE THE FOUR LARGE FLANGE BOLTS THAT RETAIN THE FLOAT ASSEMBLY, WITH FUEL IN THE TANK!**

⚠ CAUTION

It is not a legal practice to fill the tank through the liquid contents gauge.

In some applications a fixed tube fuel indicator is used in place of a float mechanism. A fixed tube indicator does not use a gauge and only indicates when the LPG tank is 80% full. The fixed tube indicator is simply a normally closed valve that is opened during refueling by the fueling attendant. When opened during refueling and the tanks LPG level is below 80%, a small amount of vapor will exit the valve. When the LPG tank level reaches 80% liquid propane will begin exiting the valve in the form of a white mist (Always wear the appropriate protective apparel when refueling LPG cylinders). In order for this type of gauge to be accurate, the tank must be positioned properly. When full (80% LPG) the valve is closed by turning the knurled knob clockwise. Typically a warning label surrounds the fixed tube gauge which reads **STOP FILLING WHEN LIQUID APPEARS.**

Service Valve

The service valve is a manually operated valve using a small hand wheel to open and close the fuel supply to the service line (fuel supply line). The service valve installs directly into the tank and has two main categories, liquid and vapor service valves. Liquid service valves used on portable LPG tanks use a 3/8" (3/8" NPT) male pipe thread on the service valve outlet for attachment of a quick disconnect coupler.

An excess flow valve is built into the inlet side of the service valve as a safety device in case of an accidental opening of the service line or damage to the service valve itself. The excess flow valve shuts off the flow of liquid propane if the flow rate of the liquid propane exceeds the maximum flow rate specified by the manufacturer.

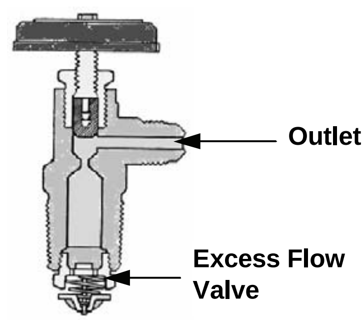


Figure 6

⚠ CAUTION

When the tank is in use the service valve should be completely open. If the valve is partly open, the vehicle may not be getting enough fuel to operate efficiently.

In addition to possibly starving the engine for fuel, a partly open valve may restrict the flow enough to prevent the excess flow valve from closing in the event of a ruptured fuel line.

Most liquid service valves have an internal hydrostatic relief valve and are usually labeled **"LIQUID WITH INTERNAL RELIEF"**. The hydrostatic relief valve protects the fuel service line between the tank and the lock off from over pressurization. The internal hydrostatic relief valve has a minimum opening pressure of 375 PSIG and a maximum pressure of 500 PSIG. These type of relief valves have an advantage over external relief valves because the propane is returned to the tank in the event of an over pressurization instead of venting the propane to atmosphere.

Quick Disconnect Coupling

The liquid withdrawal or service valve on a DOT tank has male threads and accepts the female portion of a quick disconnect coupling (Figure 8). The female portion is adapted to the liquid hose going to the fuel system. Both halves are equipped with 100% shutoffs, which open when coupled together to allow fuel flow. The coupler has two seals. One is an o-ring and the other is a flat washer. The o-ring prevents leakage from the shaft on the other coupling and the flat washer seals when the coupler is fully connected.

NOTE: The flat seal and / or the o-ring will sometimes pop off when disconnecting and slide up the shaft of the mating connector, causing the valve not to open when fully mated. The extra washer or o-ring must be removed from the shaft and the coupling reconnected.

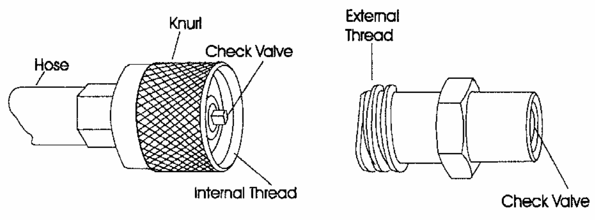


Figure 8

Filler Valve

The liquid filler valve (Figure 9) has a male thread to receive a fuel nozzle and typically has a plastic or brass screw on cap that is retained with a small chain or plastic band to keep debris out of the filler valve. The filler valve is a one-way flow device that uses two check valves to allow fuel to enter the tank but prevent it from exiting. Both check valves are backpressure type check valves, designed so that backpressure from the tank assists the check valves own spring pressure to close the valve. The first valve uses a neoprene on metal seal and the second valve uses a metal on metal seal.

A weakness ring is machined into the filler valve just above the check valves and will allow the filler valve to shear off in case of an accident. The valve will break or shear off above the check valves so that the tank will be sealed and no liquid propane can escape.

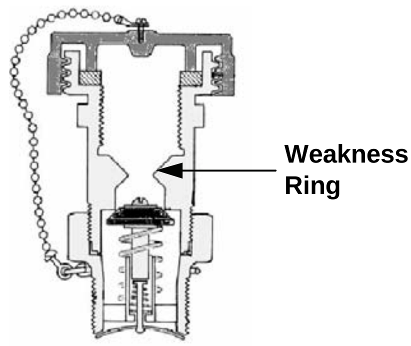


Figure 9

Regulatory Compliance

EPA / CARB Emissions Certification

When properly applied and calibrated, ’s MI-07 control system is capable of meeting EPA 2007 LSI emission standards (40 CFR Part 1048.101) when operating properly with an approved three-way catalyst. The emission standards, including appropriate deterioration factors over the useful life of the system, are as follows:

HC+NOx: 2.0 g/hp-hr [2.7 g/kW-hr]
CO: 3.3 g/hp-hr [4.4 g/kW-hr]

Evaporative emissions comply with 40 CFR Part 1048.105. These standards apply only to volatile liquid fuels such as gasoline. Note that the engine crankcase must be closed.

North American Compliance

The N-2007 regulator is UL listed per Category ITPV LP-Gas Accessories, Automotive Type.

The N-2007 regulator and CA100 mixer have tamper-resistant features approved by CARB.

Special Conditions for Safe Use

Field wiring must be suitable for at least 248°F (120°C).

SECM-48 inputs are classified as permanently connected IEC measurement Category I. To avoid the danger of electric shock, do not use inputs to make measurements within measurement categories II, III, or IV.

SECM-48 input power must be supplied from a power supply/battery charger certified to IEC standard with a SELV (Safety Extra Low Voltage) classified output.

SECM-48 inputs and outputs may only be connected to other circuits certified as SELV (Safety Extra Low Voltage).

⚠ WARNING—EXPLOSION HAZARD

Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2, or Zone 2 applications.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).

2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.

3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

Abbreviations

ACFM	Actual cubic feet per minute at the specified suction conditions
AFR	Air fuel ratio
BHP	Brake horsepower
Bi-Fuel	Able to operate on either of two fuels
CTS	Coolant temperature sensor
CNG	Compressed natural gas
Dual Fuel	Able to run simultaneously on two fuels, e.g. diesel and natural gas. Often this term is incorrectly used to describe bi-fuel operation. Spark-ignited engines are typically bi-fuel while compression ignition engines are dual-fuel.
ECM	Engine control module
FPP	Foot pedal position
FPV	Fuel primer valve
FTS	Fuel temperature sensor
FTV	Fuel trim valve
GPM	Gallons per minute of flow
HEGO	Heated exhaust gas oxygen (sensor)
LAT	Limited-angle torque motor
LPG	Liquified petroleum gas
MAP	Manifold absolute pressure
MAT	Manifold air temperature
MIL	Malfunction indicator lamp
MOR	Manufacturer of record for emissions certification on the engine
OEM	Original equipment manufacturer
PHI	Relative fuel-air ratio or percent of stoichiometric fuel (actual fuel-air ratio / stoichiometric fuel-air ratio)
RPM	Revolutions per minute
SECM	Small engine control module
TMAP	Temperature and manifold absolute pressure
TPS	Throttle position sensor
VDC	Voltage of direct current type
VE	Volumetric efficiency
WOT	Wide open throttle